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A publication of THE SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS *and* THE PALEONTOLOGICAL SOCIETY *with the generous support and cooperation of* THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS *and* THE GEOLOGICAL SOCIETY OF AMERICA

VOLUME 34 MARCH, 1960 NUMBER 2

NEW PENNSYLVANIAN BRACHIOPODA FROM SOUTHWEST MISSOURI

R. D. HOARE
Bowling Green State University, Bowling Green, Ohio

ABSTRACT—Extensive collections made from the lower portion of the Cabaniss subgroup, the upper portion of the Krebs subgroup and deposits of Atokan age in Southwest Missouri contain several new forms of Brachiopoda. The genus *Desmoinesia* is erected to contain specimens which have previously been included under the genus *Marginifera* but which lack the diagnostic features of the latter genus. This genus contains the species *D. muricatina* (Norwood & Pratten) and *D. nana* (Meek & Worthen). The genus *Eolissochonetes*, containing *E. laevis* (Keyes) and *E. bilobatus* n. sp., is erected for specimens which are transitory between the genera *Mesolobus* and *Lissochonetes*.

Also among the Productacea *Dictyoclostus tiawahensis*, n. sp., *Linoproductus planiventralis*, n. sp., *L. echinatus*, n. sp. and *L. distortus*, n. sp., are described. *Composita tetralobata*, n. sp., is erected in the Family Arthyridae.

INTRODUCTION

DURING a study of faunal differences associated with the Krebs-Cabaniss horizon in southwest Missouri, a project sponsored by the Missouri State Division of Geology and Water Resources, several new forms of invertebrates were encountered. Among these were several brachiopods which are in part diagnostic of the faunal differences.

Many workers have described faunas from this general area in the past, but since the adaption of a classification of the pre-Marmaton Desmoinesian strata in this region (Searight *et al.*, 1953), it is possible to tie the faunas more concisely with the stratigraphy. Publication of the complete faunas is contemplated for the near future, at which time a discussion of the stratigraphic significances will be included.

The Department of Geology of the University of Missouri provided research facilities and the prints for the photographs. The study is part of a dissertation used partially to fulfill the requirements for the degree of Doctor of Philosophy at the University of Missouri. Publication is authorized by the State Geologist, Missouri State Division of Geology and Water Resources. The repository numbers listed in the systematics are for specimens contained in the University of Missouri repository.

LOCALITIES

Locality 1.—Barton Co., Mo., about 1.5 mi. west of Mindenmines on U. S. 160 and 1 mile north from the highway on the Kansas-Missouri state-line road. SW¼ sec. 31, T. 32 N., R. 33 W. (A) Tiawah limestone and (B)

underlying black shale exposed in the face of a strip mine and on waste banks.

Locality 2.—Barton Co., Mo., approximately 1.0 mi. west of Liberal. SW¼NW¼ sec. 3, T. 32 N., R. 33 W. The Seville limestone is exposed in the bed of a tributary to Second Nicolson Creek about 300 feet upstream from where the stream crosses the section road.

Locality 3.—Barton Co., Mo., about 1.5 mi. west of Liberal on the township road between secs. 33 and 4, T. 32 N. and T. 33 N., R. 33 W. The cap rock of the Rowe coal is exposed in the road banks just east of the bridge over the Second Nicolson Creek.

Locality 4.—Barton Co., Mo., about 3.0 mi. northwest of Liberal, E½SW¼ sec. 21, T. 33 N., R. 33 W. Seville limestone occurs as float about 50 feet from the west side of the road.

Locality 6.—Barton Co., Mo., approximately 2.0 mi. west of Liberal, NE¼NW¼ sec. 9, T. 32 N., R. 33 W. Seville limestone is exposed in field 50 feet west of the banks of First Nicolson Creek.

Locality 7.—Vernon Co., Mo., approximately 3.5 mi. northwest of Nevada, SW¼SE¼ sec. 34, T. 36 N., R. 32 W. Seville limestone is exposed in the road bed.

Locality 8.—Vernon Co., Mo., about 0.5 mi. northwest of Deerfield, NW¼SW¼ sec. 6, T. 35 N., R. 32 W. Seville limestone is exposed in the face of an old quarry on the east side of County Hwy. H. just before it crosses the Marmaton River.

Locality 9.—Henry Co., Mo., approximately 3.0 mi. southeast of Clinton, SW¼ sec. 17, T. 41 N., R. 25 W. Seville limestone occurs on waste banks of the old Wastell Mine on the east side of Dumping Creek.

Locality 10.—St. Clair Co., Mo., approximately 1.0 mi. southeast of Appleton City, sec. 9, T. 39 N., R. 28 W. (A) Tiawah limestone and (B) underlying black shale are exposed in the face of the pit and on the waste banks of the Pioneer Mine.

Locality 11.—Barton Co., Mo., approximately 1.5 mi. northwest of Mindenmines, SE¼ sec. 30, T. 32 N., R. 33 W. (B) Tiawah limestone and (A) underlying black shale are exposed in the face of the pit and on the waste banks just northeast of the railroad running northwest out of Mindenmines.

Locality 12.—Crawford Co., Kans., about 0.5 mi. east of Frontenac on the south side of U. S. Hwy. 160, N½ sec. 4, T. 30 S., R. 25 E. Robinson shale, limestone and concretions occur on the waste banks of the old strip mine.

Locality 13.—Barton Co., Mo., about 4.75 miles north of the junction of U. S. Hwys. 71 and 160 on Hwy. 71. NE¼NE¼ sec. 13, T. 33 N., R. 31 W. Seville limestone is exposed in the bed of the tributary to Dry Wood Creek about 100 yds. west of the highway.

Locality 14.—Vernon Co., Mo., approximately 6.0 mi. southwest of Nevada, NE¼NW¼ sec. 29, T. 35 N., R. 32 W. Seville limestone is exposed in the bank of Hackberry Branch just west of the bridge where the north-south county road crosses the stream about 500 feet north of Hackberry School.

Locality 15.—Vernon Co., Mo., approximately 5.5 mi. southwest of Nevada, NE¼SE¼ sec. 20, T. 35 N., R. 32 W. Seville limestone is exposed in the bed of a tributary to Hackberry Branch about 800 ft. west of bridge where county road crosses the stream.

Locality 16.—Vernon Co., Mo., approximately 0.5 mi. north of Deerfield, SE¼SE¼ sec. 1, T. 35 N., R. 33 W. Seville limestone is exposed in the face of the old quarry on the west side of County Hwy. H. just south of the Marmaton River.

Locality 17.—Vernon Co., Mo., approximately 2.25 mi. northwest of Deerfield, NE¼SW¼ sec. 35, T. 36 N., R. 33 W. Seville limestone is exposed on the banks of the Marmaton River.

Locality 18.—Vernon Co., Mo., about 4.0 mi. south of Deerfield, SE¼SE¼ sec. 25, T. 35 N., R. 33 W. Seville limestone is exposed on the east bank of Dry Wood Creek near the section line between secs. 25 and 36.

Locality 19.—Vernon Co., Mo., about 3.0 mi. northwest of Moundville, SE¼NE¼N⅓ sec. 3, T. 34 N., R. 33 W. Seville limestone is exposed in the bed of a tributary to Dry Wood Creek just west of the bridge where the section road crosses the stream.

Locality 20.—Vernon Co., Mo., about 4.5 mi. west of Moundville, NW¼NE¼C ⅓ sec. 3, T. 34 N., R. 33 W. Seville limestone is exposed on the east side of Dry Wood Creek about 30 yds. from the creek bank.

Locality 21.—Vernon Co., Mo., approxi-

mately 1.0 mi. southwest of Moundville on County Hwy. F, NE¼SE¼ sec. 6 and W½ sec. 5, T. 34 N., R. 32 W. Tiawah limestone is exposed in the face of the strip pit and on the waste banks.

Locality 22.—Vernon Co., Mo., approximately 1.5 mi. northeast of Arthur, SE¼SW¼ sec. 33, T. 38 N., R. 31 W. Robinson Branch shale and limestone are exposed in the face of a strip mine and on waste banks.

Locality 23.—Vernon Co., Mo., approximately 3.5 mi. northeast of Arthur, just southeast of Carbon Center, NW¼SW¼ sec. 26, T. 38 N., R. 31 W. Robinson Branch shale is exposed on the waste banks of the old Jonnum Mine.

Locality 24.—Bates Co., Mo., about 0.3 mi. north of Rich Hill approx. 200 yds. west of U. S. Hwy. 71 in the SW¼NE¼ sec. 5, T. 38 N., R. 31 W. Robinson Branch shale is exposed in the strip mine and on waste banks.

Localtiy 25.—Henry Co., Mo., approximately 2.0 mi. north of Montrose, SE¼ sec. 2, T. 40 N., R. 28 W. (A) Tiawah limestone and (B) underlying black shale are exposed in the face of a strip pit and on waste banks.

Locality 26.—Henry Co., Mo., about 1.0 mi. east of Montrose, SE¼NE¼ sec. 13, T. 40 N., R. 28 W. Tiawah limestone is exposed on waste banks of an old strip mine.

Locality 27.—Henry Co., Mo., approximately 2.5 mi. east of Montrose, SE¼NW¼ sec. 17, T. 40 N., R. 27 W. (A) Tiawah limestone and (B) underlying black shale are exposed in a small strip pit on the west side of the county road just east of Bear Creek.

Locality 28.—Henry Co., Mo., approximately 2.0 mi. north of Harvey, SW¼NE¼ sec. 36, T. 43 N., R. 27 W. Tiawah is exposed in the bed of Cottonwood Creek, a tributary to Honey Creek.

Locality 29.—Henry Co., Mo., approximately 2.0 mi. north of Harvey, E½ sec. 36, T. 43 N., R. 27 W. (A) Tiawah limestone and (B) underlying black shale are exposed in the face of the strip mine and on waste banks from a large stripping operation.

Locality 30.—Henry Co., Mo., about 0.25 mi. northeast of Lewis, SE¼NE¼SW¼ sec. 9, T. 42 N., R. 25 W. Tiawah limestone is exposed in a field near an old mine shaft just west of Tebo Creek on the north side of road.

Locality 31.—Henry Co., Mo., about 0.25 mi. northeast of Lewis, NE¼NE¼SE¼ sec. 9, T. 42 N., R. 25 W. Concretions and shale over the Weir-Pittsburg coal (tentative assignment) are exposed on waste banks of the Carroll Mine on the west side of Tebo Creek.

Locality 32.—Henry Co., Mo., about 2.75 mi. north of Germantown, NW¼SW¼NW¼ sec. 27, T. 41 N., R. 28 W. The Tiawah limestone and the concretions and shale under the Tiawah are exposed in the strip face and on the waste banks of the Power Co. Mine just east of County Hwy. K. The collection is from the shale and concretions.

Locality 33.—Henry Co., Mo., approximately 1.5 mi. southeast of Lewis, NE¼SE¼NW¼ sec. 22, T. 42 N., R. 25 W. Concretions and shale over the Weir-Pittsburg coal (tentative assignment) are exposed on waste banks of the old Crowe-Brady Mine.

Locality 34.—Johnson Co., Mo., on the northeast edge of Bowen, SE¼ sec. 28, T. 44 N., R. 24 W. Shale over the Tebo coal is exposed on the old dump from an air hole on the north side of the road.

Locality 35.—Henry Co., Mo., approximately 1.0 mi. east of Bowen, NE¼NW¼ sec. 33, T. 44 N., R. 24 W. Tiawah limestone and the underlying black shale are exposed on waste banks of an old strip mine. The collection is from the shale.

Locality 37.—Miller Co., Mo., about 2.5 mi. southwest of Eldon. NW¼SE¼ sec. 7, T. 41 N., R. 15 W. Limited Atokan deposit, limestone, coal, and shale are exposed on the dump of an old mine on the Neville Farm.

SYSTEMATIC PALEONTOLOGY

Phylum BRACHIOPODA
Class ARTICULATA
Order STROPHOMENIDA
Suborder PRODUCTACEA
Family CHONETIDAE Bronn, 1862;
(emend. Hall & Clarke, 1895)

The following chonetid genera were identified in collections from the lower Desmoinesian portion of the Pennsylvanian section in southwestern Missouri:

Chonetina Krotow, 1888
Mesolobus Dunbar & Condra, 1932
Eolissochonetes Hoare, n. gen.

The new genus *Eolissochonetes* is being proposed for primitive or transitional specimens which grade from *Mesolobus mesolobus* var. *decipiens* toward the genus *Lissochonetes*. The possibility of development of the genus *Lissochonetes* from the genus *Mesolobus* was first noted by Girty (1915). The shape of *Eolissochonetes*, showing transitional features, adds substantially to this observation.

Although it has been reported above and below the portion of the stratigraphic column concerned in this study at other places in the Mid-Continent area, the genus *Chonetes* is conspicuous by its absence in the collections under consideration here. With further study, this absence may be found to be widespread raising the possibility that the higher Pennsylvanian forms are actually homeomorphs of *Chonetes* which occur lower in the Pennsylvanian as well as below it.

The genus *Mesolobus* is perhaps one of the most abundant and diagnostic fossils found. The restricted range of the species *M. striatus* is pertinent to the revised classification of the Desmoinesian Series (Searight *et al.*, 1953).

For a detailed resume of the Chonetidae, see Dunbar & Condra (1932), who give a complete list of genera and subgenera with an artificial key for their identification.

Genus EOLISSOCHONETES Hoare, n. gen.

Type species: *Chonetes laevis* Keyes.

Description.—The shells are subrectangular and in some forms bear a broad low sulcus on the pedicle valve. The cardinal extremities may be slightly rounded, right angled, or produced.

The interiors of both valves resemble those of *Mesolobus* more closely than those of *Chonetes*. On the interior of the brachial valve a long, fairly high median septum is present. Radial rows of papillae are also present which in some cases, where the shell is thickened, have been fused to form radial ridges.

Discussion.—This genus is proposed to include a group of smooth chonetids present in the Cabaniss group in southwestern Missouri. All the evidence indicates that this genus was directly derived from *Mesolobus mesolobus* var. *decipiens* and forms a transitional genus between this variety of *Mesolobus* and the genus *Lissochonetes*. The suggestion of Girty (1915, p. 64) and also by Dunbar & Condra (1932, p. 169) that *Lissochonetes* was derived from *M. mesolobus decipiens* is further substantiated by this group. The fact that a strong median septum is present easily separates these shells from *Lissochonetes* and likewise shows their close affinity to *Mesolobus*. In many cases it is difficult to separate specimens of this new genus from the variety *decipiens* since they are completely transitional. Several authors have noted the presence of smooth or nonlobate *Mesolobus* and have included these in the variety *decipiens*. It seems feasible to assume that most, if not all, of these forms would fall into this new genus. The genus *Mesolobus* was erected for those forms containing three lobes on the pedicle valve. When the middle or all lobes are lacking the specimens do not meet the requirements for that genus. On a number of specimens, of both *Eolissochonetes* and *Mesolobus*, the brachial median septum has been punched through the ventral valve by compaction. When this happens in *Eolissochonetes* a third lobe appears to be present, but can be easily identified as false in the majority of cases. It is apparent that in the development of *Lissochonetes*, through the transitional genus *Eolissochonetes*, the middle lobe of *Mesolobus* vanished prior to the disappearance or reduction of the brachial median septum.

Occurrence.—The genus *Eolissochonetes* was not collected lower in the section than the shale underlying the Tiawah limestone and ranges up to at least the Robinson Branch shale in southwestern Missouri.

EOLISSOCHONETES LAEVIS (Keyes)
Pl. 31, figs. 12–16

Chonetes laevis KEYES, 1888, Proc. Phila. Acad. Nat. Sci., p. 229, pl. 12, figs. 3a,b; ——, 1891, Proc. Phila. Acad. Nat. Sci., p. 246; ——, 1894, Missouri Geol. Survey, v. 5, pt. 2, p. 55,56, pl. 37, figs. 5a,b; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2nd ser., Bull. 5, p. 166, 167.

Description.—Shell medium-sized, widest at or just anterior to the hinge-line. The width is approximately one and one-half times the length. An average specimen measures 15.0 mm. wide, 10.0 mm. long, and 2.0 mm. thick.

The cardinal extremities are right angled, rounded, or slightly produced. The lateral margins are either slightly concave or straight anterior to the cardinal extremities, and round smoothly into the anterior margin which is nearly straight. The greatest convexity is just anterior to the beak. A very faint, broad, shallow sulcus is present on a few specimens. The diverging humps on either side of the sulcus are not greatly raised. The pedicle valve is convex, the brachial concave, fitting closely together.

The surfaces of both valves are smooth except for growth lines. No trace of true radial striation is present.

The cardinal areas of both valves are narrow and tapering. That of the brachial valve is slightly wider than the pedicle. The cardinal spines number five to seven on each side of the beak and are straight, diverging from the hinge-line laterally at an angle between 35° and 40°. The spines are smaller and shorter near the beak.

The interior of the pedicle valve is like that of *E. bilobatus* except that the teeth are shorter. The interior of the brachial valve, except for the ears, is completely covered with papillae arranged in radial rows. There is little or no difference in the size of the papillae throughout the valve. The muscle scar areas are not impressed and also contain papillae. A long median septum originates just anterior to the cardinal process and extends almost to the anterior margin. It is highest at the anterior end. The areas adjacent to the septum are not thickened greatly. A pair of crural lamellae diverge from the cardinal process and extend for a short distance approximately parallel to the hinge-line. The dental sockets are enclosed between the crural lamellae and the cardinal area. The cardinal process is small and low. Four slightly diverging ridges contain a small muscle facet between each lateral pair on the cardinal process.

Discussion.—The less-produced cardinal extremities, flatter valves, thinner shell, more quadrate outline, and the lack of a chilidium separate this species morphologically from *Eolissochonetes bilobatus*. Stratigraphically, *E. laevis* occurs abundantly only in the upper portion of the section studied, the Robinson Branch shale. At only one locality did this form occur in the black shale under the Tiawah limestone in association with *E. bilobatus*. The latter species appears to be restricted to the lower portion of the Cabaniss group.

Occurrence.—Abundant in the Robinson Branch shale at locality 22 and rare in the black shale under the Tiawah limestone at locality 10B.

Repository.—UM 13128–13133.

EOLISSOCHONETES BILOBATUS
Hoare, n. sp.
Pl. 31, figs. 17–20

Description.—Shell widest at the hinge-line, medium-sized, the width not quite twice the length. The thickness is approximately one-third as great as the length. The average width is 15.0 mm., length 9.0 mm., and thickness 3.0 mm.

The cardinal extremities are slightly produced. The lateral margins are concave anterior to the extremities then round smoothly into the anterior margin which is straight, but may be faintly sinuate. The surface of both valves is smooth except for growth lines. A false impression of radial striation may be present as a result of exfoliation and the appearance of the internal papillae. Both valves are thick.

The pedicle valve is convex and is either with or without a shallow broad sulcus. The greatest convexity is present just anterior to the beak where two broad low humps diverge towards the anterior margin at an angle of approximately 60°. The brachial valve is concave and closely fits into the pedicle.

The cardinal areas of both valves are narrow and taper towards the cardinal extremities. The brachial area is slightly wider than that of the pedicle valve. Cardinal spines are present numbering six or seven on each side of the beak. The spines are smallest toward the beak, straight, and inclined from the hinge-line at an angle of approximately 35°.

The interior of the pedicle valve contains a high median septum under the beak which becomes very low within a space of 2–3 mm. and extends slightly past mid-length of the valve. The interior, except for the muscle scars, is covered with radiating rows of papillae, one or two rows of which, on both sides of the median septum, are enlarged.

The diductor scars are large and subtriangular. The adductors are small and oval lying close to the median septum. The hinge teeth are wide, short and rounded. Dental lamellae are absent. A small deltidium partially closes the delthyrium.

The interior of the brachial valve bears a median septum which extends from a point just anterior to the cardinal process approximately three-fourths the length of the shell. It is highest at the anterior end. Two broad ridge-like crural lamellae extend from the base of the cardinal process nearly parallel to the hinge-line. The dental sockets are present between the crural lamellae and the cardinal area. The cardinal process is short and marked by four ridges, each lateral pair containing a muscular facet. A small chilidium is present at the base of the cardinal process. The adductor scars are small and triangular, and are close to the median septum. The diductor scars are large and subtriangular. The interior surface is covered with radial rows of papillae, those near the free margins being smaller than the rest. The lobate areas adjacent to the median septum are somewhat thickened and in many instances the papillae are fused into radial ridges.

Discussion.—It has been possible to distinguish two species of the genus *Eolissochonetes*. These are separated not only on a morphological basis but also stratigraphically. *Eolissochonetes bilobatus* has a greater length–width ratio and thicker shell material than *E. laevis*. The former species also has more pronounced cardinal extremities, a deeper shell, and a chilidium at the base of the cardinal process which distinguishes it from *E. laevis*. The lobate areas on the internal surface of the brachial valve in *E. laevis* are not greatly thickened and the papillae seldom fuse into radial ridges. There is an almost complete lack of any indication of a mesial sulcus on the pedicle valve of *E. laevis*, although this may be due in part to compaction.

Type locality.—Locality 10B in the Pioneer strip mine about one mile southeast of Appleton City, St. Clair Co., Mo., in sec. 9, T. 39 N., R. 29 W. The Tiawah limestone and underlying black shale are exposed in the strip face and occur on the waste banks. The holotype and some of the paratypes were collected from the black shale. The associated fauna consists mainly of numerous chonetids, productids, and spiriferoids.

Occurrence.—Abundant in the black shale under the Tiawah limestone at localities 10B and 29B. It is rare in the Tiawah limestone at localities 10A and 29A.

Holotype.—UM 13122; paratypes, 13123-13127.

Genus MESOLOBUS Dunbar & Condra, 1932

MESOLOBUS STRIATUS Hoare, n. sp.

Pl. 31, figs. 7–11

Mesolobus mesolobus GIRTY, 1915, U. S. Geol. Survey, Bull. 544, figs. 10,11; MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 179,180, pl. 7, figs. 14,15; DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2nd ser., Bull. 5, p. 161–164, pl. 20, figs. 2a,b (not fig. 1).
Mesolobus striatus WELLER & MCGEHEE, 1933, Jour. Paleontology, v. 7, p. 109,110 (*nomen nudum*).

Description.—Medium-sized, subquadrate *Mesolobus* which are radially striate. The greatest width is at or near the hinge-line with the cardinal extremities produced or at right angles. An average specimen measures 11.3 mm. wide, 6.4 mm. long, and 2.2 mm. thick. A large specimen has a width of 15.7 mm., length of 9.6 mm., and a thickness of 3.1 mm. The lateral margins are slightly rounded, slightly concave just anterior to the cardinal extremities, and round smoothly into the anterior margin which is sinuate. Six to eight cardinal spines are present on each side of the pedicle beak.

The pedicle valve in most specimens has a low convexity, although this may be due in part to crushing, since a few specimens are more convex. The median lobe is distinct but quite narrow and is lower than the lateral lobes. The radial striation is distinct and more prominent near the anterior margin where eight to eleven striae occupy the space of 1.0 mm. The striae multiply by bifurcation, which is most prominent near the margins. The brachial valve, which is slightly concave, is striate and possesses a marked medial sulcus.

The interior of the pedicle valve contains a short high septum under the beak. The surface is covered with papillae arranged radially near the margins. The muscle scars are deeply impressed. The cardinal area is

marked by fine transverse lines. The teeth are of moderate size and slightly irregular in shape. A callus-like deltidium fills approximately one-half of the delthyrium.

Internally the brachial valve has a long blade-like median septum which extends four-fifths the length of the valve. It is highest anteriorly. A pair of ridges diverge from the base of the cardinal process and lie almost parallel to the hinge-line. A pair of dental sockets is present between the ridges and the hinge-line at the base of the cardinal process. A second pair of low ridges diverge from the base of the cardinal process forming an angle of approximately 90°. They extend to mid-length of the valve and are topped by a row of heavy papillae. Two flabulate elevated areas flank the median septum. They are marked by rows of fused papillae forming lamellae. The anterior and lateral marginal areas are radially papillate. The cardinal process is low and wide. The posterior face is marked by two pairs of slightly diverging ridges containing a pair of small muscle facets between them. A small chilidium is present at the base of the cardinal process. The adductor muscle scars lie close to the posterior end of the median septum and are small and elongate. The diductor scars lie between the two pairs of diverging ridges and are larger and more subtriangular than the adductor scars.

Discussion.—It is possible that two varieties of this species could be distinguished. Some of the shells are more alate and others have a greater convexity of the pedicle valve but some forms are both alate and more convex while others are more convex but not alate. There seems to be complete transition in the forms present and it would serve no purpose to subdivide them at present.

The name *Mesolobus striatus* was applied to these forms by Weller & McGehee (1933) who separated it from the *Mesolobus mesolobus* group on the basis of the surface ornamentation. Previous to this time it was commonly thought that *Mesolobus mesolobus* was a striate form, having been described as such by Norwood & Pratten (1855) and called *Chonetes mesolobus*. The original types, which have been lost, were collected from the Pennsylvanian near Bellville, Illinois and Charbonniere, Missouri, and could not have been striate since striate forms do not occur as high in the section as is exposed in these areas. Possibly the specimens were striate and became mixed into a collection from these areas. It is more likely that they were pseudostriate, caused by partial exfoliation of the shell and exposing the pseudopunctae, thus giving the illusion of striation. All varieties of *Mesolobus mesolobus* show pseudostriation caused by exfoliation of the shell and the exposure of internal structures.

Since Weller & McGehee have not described and illustrated type material for this species the name is a *nomen nudum*, but because it has been commonly used in the literature and serves as a good zone fossil the original name is here preserved and validated.

Type locality.—Locality 9 located approximately 3 miles southeast of Clinton, Henry Co., Mo., in the old Wastell Mine on the east side of Dumping Creek SW¼ sec. 17, T. 41 N., R. 25 W. The Seville limestone is present as blocks on the old mine dump and contains an abundant fauna. Associated with *Mesolobus striatus* are numerous productids and spiriferoids, and less numerous gastropods, pelecypods, corals, and bryozoans.

Occurrence.—This species does not occur above the Krebs-Cabaniss boundary in Missouri. It is abundant in the Burgner formation at locality 37 and in the Seville limestone at localities 2, 6, 7, 8, 9, 14 and 16. It is common in the Seville limestone at localities 13, 15, 18 and rare at locality 20.

Holotype.—UM 13158; paratypes, 13159–13166.

Family Dictyoclostidae Stehli, 1954

The Dictyoclostidae are among the most common fossils found in this portion of the Pennsylvanian section. At some locations the shells are so closely packed that they nearly form a coquina.

The genera collected were:

Dictyoclostus Muir-Wood, 1930
Marginifera Waagen, 1884
Desmoinesia Hoare, n. gen.
Linoproductus Chao, 1927

An abundant group of shells, heretofore

referred to the genus *Marginifera*, have been placed in the new genus *Desmoinesia*. Two species, *D. muricatina* (Norwood & Pratten) and *D. nana* (Meek & Worthen) are included here. The name *Desmoinesia* is used since the genus is believed to be restricted to the Desmoinesian series.

Dunbar & Condra (1932) have synthesized the work of European and American authors and give a great deal of information on the identification, principles of generic classification and shell structure of the productids.

Genus DICTYOCLOSTUS
Muir-Wood, 1930
DICTYOCLOSTUS TIAWAHENSIS
Hoare, n. sp.
Pl. 32, figs. 5–9

Description.—Shell large, wider than long, and deeply convex. Greatest width at or near the hinge-line. Ears large, heavy, and strongly arched. A typical specimen measures 7.3 cm. wide, 4.57 cm. long, and 3.55 cm. thick.

On a complete specimen a strong geniculation is present at mid-length at the point of greatest convexity. The beak is large and broadly obtuse. The umbo is broad and only slightly inflated. The surface is marked by radial costae of which seven to eight cover the space of 1.0 cm. on the anterior slope. Near the extreme lateral and anterior margins the costae are much finer, caused by bifurcation, and 12 to 20 cover the space of 1.0 cm. The posterior half of the pedicle valve is strongly reticulate caused by the crossing of the costae by concentric rugae. A few large spines are scattered over the surface. A row of small cardinal spines are present and also a row of coarse spines at the base of the umbonal slope. A shallow sulcus

(*Text continued on next page*)

EXPLANATION OF PLATE 31

(All figures ×2)

FIG. *1,2*—*Mesolobus mesolobus* var. *lioderma* Dunbar & Condra. Pedicle and brachial interior views from the Robinson Branch sh., UM loc. 22, UM 13149, 13152.

3,4—*Mesolobus mesolobus* var. *euampygus* (Girty). Pedicle view from shale under the Tiawah ls., UM loc. 29B, UM 13142; interior of brachial valve from the Robinson Branch sh., UM loc. 22, UM 13145.

5,6—*Mesolobus mesolobus* var. *decipiens* (Girty). Brachial interior from the shale under the Tiawah ls., UM loc. 10B, UM 13136; pedicle view, showing the medial septum punched through the middle lobe, from the Robinson Branch sh., UM loc. 22, UM 13138.

7–11—*Mesolobus striatus*, n. sp. Brachial view of a paratype, UM 13162; pedicle view of holotype, UM 13158; interior of pedicle, pedicle, and interior of brachial views of paratypes, UM 13159, 13161, 13163; all from the Seville ls., UM loc. 9.

12–16—*Eolissochonetes laevis* (Keyes), n. gen. Pedicle, internal pedicle, brachial, pedicle, and internal brachial views, from Robinson Branch sh., UM loc. 22, UM 13131, 13128, 13132, 13130, 13129.

17–20—*Eolissochonetes bilobatus*, n. gen., n. sp. Brachial view, from shale under Tiawah ls., of paratype, UM loc. 10B, UM 13124; interior of pedicle valve, from shale under Tiawah ls., of paratype, UM loc. 29B, UM 13125; pedicle view, from shale under Tiawah ls., of holotype, UM loc. 10B, UM 13122; interior of brachial valve of paratype, UM loc. 29B, UM 13123.

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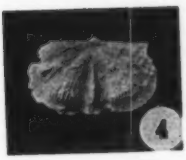
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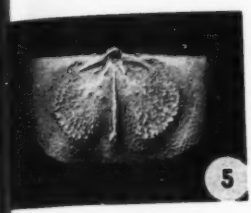
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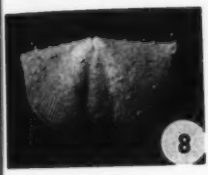
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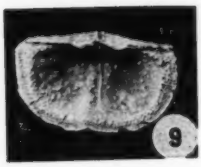
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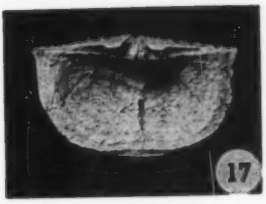
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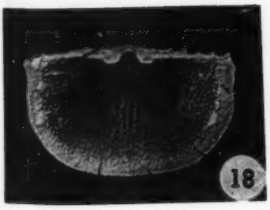
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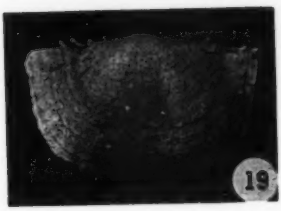
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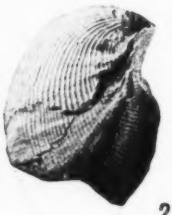

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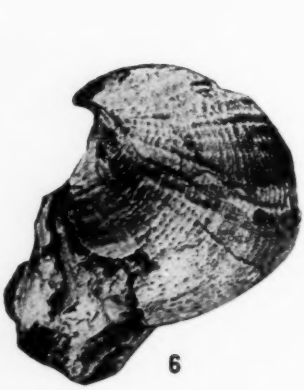

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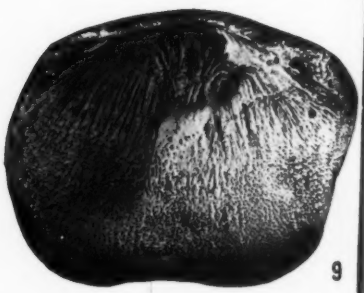

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begins on the umbo, becoming more pronounced on the anterior slope.

The brachial exterior is slightly concave; more so near the anterior margin where a pronounced geniculation is present. The surface is reticulate and does not bear spines.

Two larger triangular diductor scars, with a radially striate structure, are present on the pedicle interior. Between these scars two smaller dendritically marked adductor scars are closely paired.

The adductor scars on the brachial valve are small, slightly raised areas close to the median septum which extends almost one-half the length of the valve. The diductor scars are larger, elevated, tasselate structures lying posterior to the adductors. A low ridge extends laterally from the adductor scars, extending three-fourths the width of the valve, then curving anteriorly before recurving posteriorly to enclose a relatively smooth brachial area. The ridge then parallels itself back to the scar areas. Heavy lateral ridges diverge from the base of the cardinal process, but die out almost immediately. The cardinal process is large, of medium height, and is distinctly tetralobed. The surface of the valve is reticulate except for the extreme margins. Numerous small spines, directed anteriorly, are scattered on the surface.

Discussion.—*Dictyoclostus tiawahensis* is larger than *D. portlockianus* and has a greater height-width ratio. Other diagnostic characters of *D. tiawahensis* are its large tetralobed process, geniculate shell, fine costae near the margins, large and strongly arched ears, and lack of a heavy ridge paralleling the hinge-line. *D. tiawahensis* is larger, more transverse, has larger more strongly arched ears, is more convex, and may have a deeper ventral sulcus than *D. americanus*. *D. tiawahensis* also lacks the heavy lateral ridges on the dorsal interior and the extra row of cardinal spines which *D. americanus* possesses.

Type locality.—Locality 11B located approximately one-half mile north of Mindenmines, Barton Co., Mo., in the SE¼ sec. 30, T. 32 N., R. 33 W. The Tiawah limestone is exposed in the old strip face and blocks are scattered abundantly over the waste banks.

(*Text continued on next page*)

EXPLANATION OF PLATE 32

(All figures ×1)

FIG. *1–3*—*Linoproductus planiventralis*, n. sp. Pedicle and lateral views of the holotype and pedicle view of a paratype, from Seville ls., UM loc. 9, UM 13243, 13244.

4—*Linoproductus distortus*, n. sp. Pedicle view of holotype, from concretions under the Tiawah ls., UM loc. 32, UM 13251.

5–9—*Dictyoclostus tiawahensis*, n. sp. Pedicle, lateral, and posterior views of holotype, from Tiawah ls., UM loc. 11B, UM 13184; interior of brachial valve and a clay cast of interior of pedicle valve of a paratype, from Tiawah ls., UM loc. 1A, UM 13185.

The holotype was collected from a block of Tiawah limestone on the waste banks and was associated with numerous spiriferoids, small productids, pelecypods and gastropods.

Occurrence.—Rare in the Tiawah limestone at localities 1A, 11B, and 25A.

Holotype—UM 13184; paratypes, 13185–13187.

Genus DESMOINESIA Hoare, n. gen.

Type species: *Productus muricatus* Norwood & Pratten.

Description.—Shell small, quadrangular to subrectangular in outline. Ears small and only slightly arched. Pedicle valve marked by subequal to equal bifurcating costae and a reticulate area, formed by rugae, on the posterior portion. Numerous spines scattered over the surface with a row usually present at the base of the umbonal slope.

Internally the brachial valve resembles that of *Marginifera*, except for the lack of an anterior margin and only partial lateral margins. Instead of having a row of pali anterior to the septum there is a large group of randomly spaced pali.

Discussion.—The lack of the marginal flange along the anterior border and the anterior portion of the lateral borders removes these shells from the genus *Marginifera*. Other differences such as the more geniculate form, larger more strongly arched ears, more pronounced mesial sulcus, finer and lower costae, and the single line of interior pali found in *Marginifera* differentiate the two genera.

Occurrence.—The genus *Desmoinesian* is abundant throughout the lower Desmoinesian Series of the Pennsylvanian section. It has been reported as high as the Lenapah limestone of the Fort Scott group. It is unknown in the Missourian series.

DESMOINESIA MURICATINA
(Norwood & Pratten)
Pl. 33, figs. 8–13

?*Productus Flemingi* ROEMER [*non* DEKONINCK], 1852, Kreid. von Texas, p. 89, pl. 11, figs. 8a,b.

Productus muricatus NORWOOD & PRATTEN [*non P. muricatus* PHILLIPS], 1854, Jour. Phila. Acad. Nat. Sci., 2nd ser., v. 3, p. 14, pl. 1, figs. 8a–e. (Date of imprint, 1855–1858); COX, 1857, Geol. Survey Kentucky Rept., v. 3, p. 573, pl. 9, fig. 6; WHITE, 1876, U. S. Geol. and Geog. Survey Terr., 2 div., Powell's Rept. Geol. Uinta Mountains, p. 90; ——, 1877, U. S. Geol. Survey W. 100th Merid. Rept., v. 4, p. 120, pl. 8, figs. 4a–c; HERRICK, 1887, Bull. Sci. Lab. Denison Univ., v. 2, p. 49; KEYES, 1886, Proc. Phila. Acad. Nat. Sci., p. 228. (Date of imprint, 1889.)

Productus longispinus KNIGHT, 1900, Univ. Wyoming, Wyoming Exptl. Sta. Bull., no. 5, pl. 3, fig .10.

Marginifera muricata GIRTY, 1903, U. S. Geol. Survey, Prof. Paper 16, p. 373, pl. 5, figs. 5–5b, 6–6b,7; ——, 1915, U. S. Geol. Survey, Bull. 544, p. 78,79, pl. 10, figs. 3–4a.

Marginifera muricata var. *missouriensis* MORNINGSTAR, 1922, Ohio Geol. Survey, 4th ser., Bull. 25, p. 184, pl. 9, figs. 1–5.

Marginifera muricatina DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2nd ser., Bull. 5, p. 222–224, pl. 35, figs. 1–10.

?*Marginifera muricatina* COOPER (*in* SHIMER & SHROCK), 1944, Index Fossils of N. Amer., p. 351, pl. 137, figs. 24–26.

Description.—Shell small, subrectangular in outline, and moderately to strongly convex. The ears are small and only slightly arched. The greatest width is usually at mid-length. A typical specimen measures 19.5 mm. wide, 13.6 mm. long, and 7.8 mm. thick. The greatest convexity is posterior to mid-length where a rounded geniculation is often present.

The beak is small and overhangs the hinge-line slightly. A faint shallow medial sulcus is present on many specimens. The surface of the pedicle valve is covered with coarse irregular costae some of which bifurcate. From seven to nine costae occupy the space of 0.5 cm. on the anterior slope. Concentric rugae crossing the costae cause the posterior portion of the valve to be reticulate. Small spines are scattered randomly over the entire surface. On some specimens a row of spines, parallel to the anterior margin, is present on the anterior slope. Three or four spines are present along the hinge-line on each side of the beak. Another row follows the base of the umbonal slope.

The brachial exterior appears to be spineless although Girty (1915) and Dunbar & Condra (1932) reported spines on a few specimens. The surface is reticulate and moderately concave.

The internal features of the pedicle valve are lightly impressed and are not distinguishable. The brachial interior bears a low median septum extending to about mid-length. A pair of low ridges diverge laterally

from the cardinal process lying nearly parallel to the hinge-line before curving anteriorly along the lateral margins where they disappear. Brachial ridges, beginning at the muscle scar area, form oval elevated areas. The recurved ends often terminate in a raised flange-like process. Eighteen to 25 stout pali occupy the area anterior to the septum and the brachial areas. Smaller papillae are scattered on the surface. The cardinal process is low, flattened, and oval in outline. Two fairly large muscular facets are separated by a medial ridge which is divided by a groove on the anterior side. The outer ridges are slightly lower than the medial ridge. The adductor scars are subtriangular areas lying close to the medial septum. They are slightly elevated and bordered by a low ridge. The diductor scars are elongate kidney-shaped areas lying posterior to the adductors. Hinge teeth and sockets are absent.

Discussion.—*Desmoinesia muricatina* is most often confused with *D. nana* (Meek & Worthen) which it resembles in general. *D. muricatina* has a greater length-width ratio and bears more numerous spines than *D. nana*. The costae on *D. muricatina* are coarser and do not subdivide, to form a finer costate margin, as in *D. nana*.

Occurrence.—Common to abundant throughout the lower Desmoinesian Series. Especially abundant in the black shales immediately underlying the limestones.

Repository.—UM 13208–13218.

DESMOINESIA NANA (Meek & Worthen)
Pl. 33, figs. 4–7

?Productus nanus MEEK & WORTHEN, 1866, Illinois Geol. Survey, v. 2, p. 320, pl. 26, figs. 4a–d.
Marginifera muricata var. *missouriensis* GIRTY, 1915, [*non* Morningstar, 1922] Missouri Bur. Geology and Mines, v. 13, p. 350, pl. 30, figs. 2–5a; KELLEY, 1930, Jour. Paleontology, v. 4, p. 145, pl. 11, figs. 6,7.
Marginifera missouriensis DUNBAR & CONDRA, 1932, Nebraska Geol. Survey, 2nd ser., Bull. 5, p. 224,225, pl. 35, figs. 11–16.

Description.—Shell small and quadrangular in outline. Ears small and moderately arched. Beak small and obtuse, overhanging the hinge-line slightly. The greatest width and convexity is at mid-length. A typical specimen measures 12.0 mm. wide, 10.9 mm. long, and 6.5 mm. thick.

The surface of the pedicle valve is covered with low rounded costae of nearly equal size. The costae multiply by bifurcation. From six to seven costae occupy the space of 0.5 cm. on the anterior slope. A band of finer costae is present along the anterior margin on specimens with a complete trail. A raised band marks the junction of the margin of the brachial valve. The posterior portion of the valve bears rugae which are coarser near the ears. A reticulate marking is formed by the rugae and costae. The lateral margins of the pedicle valve anterior to the hinge-line form a right angle with the hinge-line with the edges directed dorsally. Numerous spines are scattered over the shell, and are more abundant near the margins. A row of spines follows the base of the umbonal slope and seems to mark a line of weakness of the shell here. Girty (1935) pointed out that many of the shells break along this line and are collected without the cardinal extremities. The surface of the brachial valve is reticulate and slightly concave. No spines were observed.

The internal features of this species were not observed in collections from this area.

Discussion.—The more quadrate outline, the stronger arching of the ears, the dorsally directed lateral margins, longer trail, and the raised band bordering the anterior margin are distinctive of this species and separate it from *Desmoinesia muricatina*. As collected in southwest Missouri *D. nana* is more restricted in its environment than *D. muricatina*. Whereas the latter species is ubiquitous through the section, *D. nana* was found only in limestones.

The species is commonly found with the extreme anterior portion of the trail missing. This has led to the formation of species which are synonyms of *Desmoinesia nana*. The specimen which Meek & Worthen described was probably unique, as thought by Dunbar & Condra (1932), but only because it had preserved an almost complete trail showing the finely costate border. In most specimens this feature is not preserved. Girty's species *Marginifera ingrata* from Colorado also shows these characteristics and possibly should be placed in the synonomy of this species. In consequence of these facts it is necessary to re-establish the

specific name used by Meek & Worthen.

Occurrence.—Abundant in the Seville limestone at localitites 2, 4, 9, 13, 14, 15 and 18. Common in the Seville limestone at localities 6, 7, 8, 19, 20 and in the cap rock of the Rowe coal at locality 3. Rare in the Seville limestone at locality 16.

Repository.—UM 13219–13223.

Genus LINOPRODUCTUS Chao, 1927

LINOPRODUCTUS PLANIVENTRALIS

Hoare, n. sp.

Pl. 32, figs. 1–3

Description.—Shell medium to large, subhemispherical, with the greatest width near mid-length. Beak small and obtuse, strongly recurved over the hinge-line. A typical specimen measures 3.5 cm. long, 4.6 cm. wide, and 2.15 cm. thick. The trail on this specimen is not complete so the length is diminished.

The pedicle valve is strongly convex lengthwise, but has a pronounced mesial flattening which occupies two-thirds to three-fourths the width of the shell. The lateral slopes are steep. The umbo is broad and not inflated. The large ears are marked by strong wrinkles and bear a double row of slender erect spines. Very few spines are present on the rest of the valve. No more than five were counted on any specimen. The costae are fine and low, increasing in number by bifurcation with six to eight occupying the space of 0.5 cm. on the anterior slope.

The brachial valve is concave and marked by fine costae and strong concentric wrinkles. The interior features were not observed.

Discussion.—Linoproductus planiventralis resembles *L. echinatus* Hoare and is probably closely related. The main differences are the more numerous spines on the ventral valve, and three rows of cardinal spines instead of two on *L. echinatus*.

Type locality.—Locality 9, located at the old Wastell Mine in the SW¼ sec. 17, T. 41 N., R. 25 W. approximately 3.0 mi. southeast of Clinton in Henry Co., Mo. The Seville limestone is present as blocks on the waste banks and contains a very abundant and varied fauna especially productids and spiriferoids.

Occurrence.—This species is common in the Seville limestone at localities 9 and 16. Fragmentary specimens from the concretions under the Tiawah limestone at locality 32 and the black shale lying beneath the Tiawah limestone at locality 25B may belong to this species.

Holotype.— UM 13244; paratypes, 13235, 13236, 13243, 13245, 13246.

LINOPRODUCTUS ECHINATUS

Hoare, n. sp.

Pl. 33, figs. 15–19

Description.—Shell medium to large, subhemispherical in shape, with large, strongly wrinkled ears. The beak is small and very obtuse. The umbo is broad and flattened. The greatest width and convexity is posterior to mid-length. A typical, incomplete specimen measures 4.3 cm. wide, 3.52 cm. long, and 2.2 cm. thick.

The pedicle valve is flattened with steep lateral slopes. Fine, low costae cover the shell; eight or nine occupy the space of 0.5 cm. on the anterior slope. Spines, in a quincuncial arrangement, are borne on the costae. The costae are thickened posterior to the spines and usually split on the anterior side. Three irregular rows of cardinal spines are present on the ears.

The brachial valve bears costae and is strongly wrinkled. Internally, a long low median septum is present. The cardinal process is low and appears trilobed. The muscle scars are indistinct, but lie closely flanking the median septum. The surface reflects the exterior markings.

Discussion.—Linoproductus echinatus seems to be more spinose than *L. planiventralis* Hoare. The number and arrangement of the spines are the only noted differences. The costae on most specimens of the species *L. planiventralis* do not split anterior to the spines as they do in the species *L. echinatus*.

Type locality.—Locality 9 located at the old Wastell Mine in the SW¼ sec. 17, T. 41 N., R. 25 W., approximately 3.0 mi. southeast of Clinton in Henry Co., Mo. The Seville limestone is present as blocks on the waste piles and contains a very abundant and varied fauna, especially productids and spiriferoids.

Occurrence.—Common in the Seville limestone at localities 9, 13, 14, 15 and 18. Also

common in the shale under the Tiawah limestone at locality 32. Fragments from the Robinson Branch shale at localities 12 and 22 may belong to this species.

Holotype.—UM 13247; paratypes, 13248-13250.

LINOPRODUCTUS DISTORTUS Hoare, n. sp.
Pl. 32, fig. 4

Description.—Shape and size of shell similar to *Linoproductus echinatus* Hoare. Large wrinkled ears bear spines. Beak small, recurved, and obtuse. Pedicle valve flattened mesially. Costae low and rounded, wider near the margins. Spines in a quincuncial arrangement with the costae sometimes splitting anterior to the spine bases. Five costae occupy the space of 0.5 cm. near the postero-lateral margins. The costae down the median line of the valve are irregular or contorted. They curve into and out of the median line forming swirls or knot-like structures which may be the base of a node or large spine. Brachial valve and interior features not observed.

Discussion.—Three fragmentary specimens form the basis for this description. The size and general shape of the shell closely resembles *Linoproductus echinatus* Hoare and the number and arrangement of the spines over the shell is similar. It is not possible to determine the arrangement of the spines near the cardinal border of this species. The main differences between the species *L. distortus* and the species *L. planiventralis* and *L. echinatus* are the coarser marginal costae and the irregular costae along the medial line on the species *L. distortus*. Except for the spinose character and the irregular medial costae the species *L. distortus* also closely resembles *L. planiventralis* Hoare.

Type locality.—Locality 32 located at the Power Co. Mine in the NW¼SW¼NW¼ sec. 27, T. 41 N., R. 28 W. north of Germantown in Henry Co., Mo. The type specimens were collected from the concretions in the black shale under the Tiawah limestone. The associated fauna consists of numerous pelecypods, gastropods, productids, and spiriferoids.

Holotype.—UM 13251; paratypes, 13252.

Order SPIRIFERIDA
Suborder SPIRIFERACEA
Genus NEOSPIRIFER Fredericks, 1919

NEOSPIRIFER GOREII var. BREVIMARGINATUS Hoare, n. var.
Pl. 33, fig. 14

Description.—Shell similar to *Neospirifer goreii* (Mather), 1915, in all respects except the slightly more pronounced sulcus and the limited lateral areas in this variety. The shell is slightly higher than wide with the greatest width at or just anterior to the hinge-line.

The surface is marked by numerous radiating costae as in *N. goreii*, the number and size being very similar. Concentric growth lines show that the immature form had a greater length-width ratio than the mature shell and differential growth took place. Two large triangular teeth are located at the sides of the triangularly shaped delthyrium. Other internal characteristics were not observed.

The specimen, a nearly complete pedicle valve, measures 32.0 mm. in height, 29.0 mm. in width, and is 11.9 mm. deep.

Discussion.—A single pedicle valve is the basis for the above description. Its excellent state of preservation and lack of distortion leaves little doubt of its validity as a distinct variety of the species *N. goreii*. The length-width ratio is distinctive.

Type locality.—Locality 37 located at the old mine on the Neville farm in the NW¼SE¼ sec. 7, T. 41 N., R. 15 W. approximately 4.0 miles southwest of Eldon in Miller Co., Mo. A light gray argillaceous limestone is present in chunks associated with a darker gray shale in the old mine dump. This limestone and part of the shale are fossiliferous, containing a fauna consisting mainly of spiriferoids and productids. The holotype came from the limestone.

Holotype.—UM 13268.

Suborder ROSTROSPIRACEA
Family ATHYRIDAE Phillips, 1841
Genus COMPOSITA Brown, 1849

COMPOSITA TETRALOBATA Hoare, n. sp.
Pl. 33, figs. 1–3

Description.—Shell medium-sized to small, suboval to subtriangular in outline, greatest width anterior to mid-length, and

greatest thickness at or slightly posterior to mid-length. The holotype measures 1.5 cm. wide, 1.55 cm. long, and 0.98 cm. thick. Measurements of a larger specimen are: width, 2.5 cm.; length, 2.54 cm.; thickness, 1.6 cm.

The pedicle beak is low and obtuse. A circular foramen perforates the beak. The lateral margins round smoothly into a sinuate anterior margin. The pedicle valve has a shallow broad sulcus that ends in a rectangularly shaped structure. A narrow subangular median sulcus is present in the larger pedicle sulcus. The brachial valve has a low broad fold which is separated from the lateral areas by narrow lateral sulci. A narrow shallow median sulcus divides the fold into two lobes. The surface is marked by numerous growth lines. The internal structures were not observed.

Discussion.—*Composita tetralobata* is similar to *C. trilobata* Dunbar and Condra. The main distinctions are the median sulcus on the brachial fold and the more rectangularly-shaped anterior margin as seen from the anterior on *C. tetralobata*. Dunbar & Condra (1932) thought that *C. trilobata* might be descended from the Mississippian species, *C. trinuclea* (Hall). It is also possible that *C. tetralobata* is an intermediate form between these two.

Type locality.—Locality 21 in an abandoned strip mine approximately one mile southwest of Moundville, Vernon Co., Mo., in the $SW\frac{1}{4}NW\frac{1}{4}$ sec. 5, T. 34 N., R. 32 W. The Tiawah limestone, about two feet thick here, contains an abundance of algae but otherwise is not very fossiliferous. A thin sandy zone near the top contains specimens of *Composita*, *Neospirifer*, productids and a few gastropods. The holotype was collected from a large block of Tiawah on the waste banks.

Occurrence.—Rare in the Tiawah limestone at locality 21 and in the shale immediately beneath the Tiawah limestone at locality 10B.

Holotype.—UM 13323; paratype, 13324.

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(*Explanation of* PLATE 33 *on next page*)

EXPLANATION OF PLATE 33

(All figures ×1 except where noted)

FIG. *1–3—Composita tetralobata*, n. sp. Brachial, anterior, and lateral views of holotype, from Tiawah ls., UM loc. 21, UM 13323.

4–7—Desmoinesia nana (Meek & Worthen), n. gen. Two anteropedicle, pedicle, and lateral views, from Seville ls., UM loc. 9, UM 13219–13222; ×2.

8–13—Desmoinesia muricatina (Norwood & Pratten), n. gen. Brachial view, from shale under Tiawah ls., UM loc. 10B, UM 13211; brachial interior, from shale under Tiawah ls., UM loc. 29B, UM 13210; lateral view, from shale under Tiawah ls., UM loc. 10B, UM 13213; pedicle view, from Robinson Branch sh., UM loc. 22, UM 13209; pedicle view, from the shale under the Tiawah ls., UM loc. 29B, UM 13212; pedicle view, from the shale under the Tiawah ls., UM loc. 29B, UM 13208; ×2.

14—Neospirifer goreii var. *brevimarginatus*, n. var. Pedicle valve of holotype, from Burgner fm., UM loc. 37, UM 13268.

15–19—Linoproductus echinatus, n. sp. Pedicle view of the holotype, from Seville ls., UM loc. 9, UM 13247; pedicle valve of a paratype, from Robinson Branch sh., UM loc. 12, UM 13248; interior of brachial valve of a paratype, from Seville ls., UM loc. 9, UM 13249; posterior and lateral views of the holotype, from Seville ls., UM loc. 9, UM 13247.

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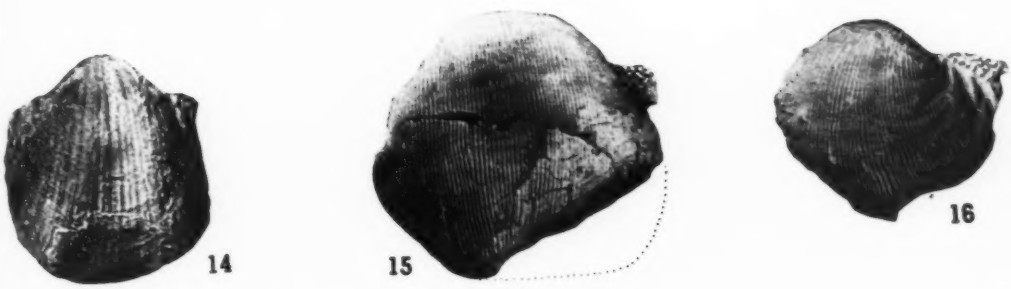

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JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 233–236, PL. 34, 2 TEXT-FIGS., MARCH, 1960

PARAPUZOSIA IN THE NORTH TEXAS CRETACEOUS

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ABSTRACT—*Parapuzosia* (*Parapuzosia*) has been found in the uppermost Austin Chalk in Ellis, Dallas, and Collin counties in northern Texas where it is an excellent stratigraphic marker. Fragments of *Parapuzosia* (*Austiniceras*), found in Cenomanian and Turonian rocks of Europe, have been reported from Texas and now the first Texas species is recorded from the upper Eagle Ford Shale south of Dallas.

IN 1928 Scott & Moore described two species of *Parapuzosia* from the Austin Chalk of Texas. These writers mentioned that giant ammonoids had been known for some time in the Texas Cretaceous but their report is the first published account of the genus from Texas. The exact stratigraphic level from which the fossils came was uncertain. These specimens were recorded by Adkins (1928) from an earlier manuscript of Scott & Moore.

Miller & Youngquist (1946) have given a rather thorough account of giant Cretaceous ammonoids and in addition described *Parapuzosia bradyi* Miller & Youngquist from Montana. The species from Texas, as well as that from Montana, are evidently of Upper Santonian or Lower Campanian age (Young, 1958).

Spath (1922) redefined *Parapuzosia* and established several new genera including *Austiniceras* for certain large ammonoids which had previously been referred to it. Matsumoto (1954) has outlined morphologic as well as stratigraphic differences among the Puzosiinae, including *Mesopuzosia*, *Austiniceras*, and *Parapuzosia* s.s.: "*Parapuzosia* thus revised occurs in Santonian and just above and below but never ranges up to Upper Campanian or Maestrichtian, whereas *Austiniceras* comes from Cenomanian and Turonian" (p. 82). Matsumoto further points out that "*Mesopuzosia* occurs abundantly in the Neogyliakian or Turonian and less commonly in the Urakawan or Coniacian *plus* Santonian of Indo-Pacific realm, while *Puzosia* ranges from Albian to Turonian" (p. 79).

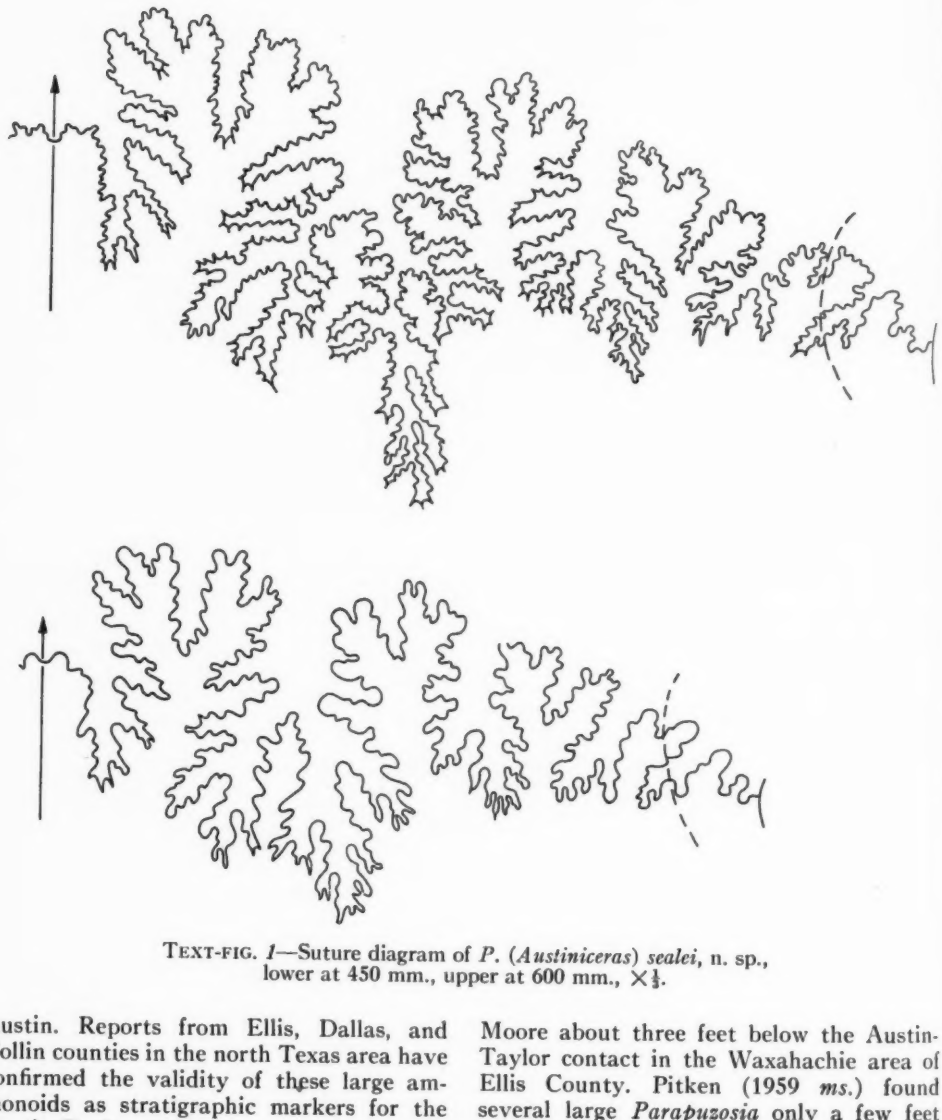
As indicated by Matsumoto the morphologic and stratigraphic evidence would suggest that *Puzosia* gave rise "in parallel" to *Mesopuzosia* and *Austiniceras* and that *Parapuzosia* and *Austiniceras* may have only subgeneric distinction as "the former is probably a direct descendant from the latter" (p. 81). Arkell, Kummel, & Wright (1957) consider *Austiniceras* as an Upper Cenomanian to Upper Turonian subgenus of *Parapuzosia*.

PARAPUZOSIA (*PARAPUZOSIA*)

The occurrence of *Parapuzosia* (*Parapuzosia*) in the upper Austin as noted by Scott & Moore (1928) was considered significant by Adkins (1933) who pointed out that the Burditt Marl, the lithologic transitional chalk and marl between the Austin and Taylor, was "paleontologically . . . approximately the zone of large cart-wheel ammonites [*Parapuzosia*]" (p. 451). Stephenson (1937) in his study of the Austin-Taylor contact did not discuss this zone but since that time many students have noticed the occurrence of *Parapuzosia* in the upper

EXPLANATION OF PLATE 34

FIG. *1–3*—*Parapuzosia* (*Austiniceras*) *sealei*, n. sp. The holotype (Southern Methodist University, 35024) from the Upper Eagle Ford Shale near Britton, Texas. ×⅓.



TEXT-FIG. *1*—Suture diagram of *P.* (*Austiniceras*) *sealei*, n. sp., lower at 450 mm., upper at 600 mm., ×¼.

Austin. Reports from Ellis, Dallas, and Collin counties in the north Texas area have confirmed the validity of these large ammonoids as stratigraphic markers for the Austin-Taylor contact.

Smith (1955 *ms.*) reports that the only distinctive fossil found in the upper "chalky marl unit" of the Austin was *Parapuzosia americana* Scott & Moore. He reported that this species ranges through 40 feet of section into the base of the Taylor in the Dallas area, but no description of occurrences in the Taylor were given. Peabody (1957 *ms.*) found a specimen some four feet in diameter which he described as *P. americana* Scott & Moore about three feet below the Austin-Taylor contact in the Waxahachie area of Ellis County. Pitken (1959 *ms.*) found several large *Parapuzosia* only a few feet below the Austin-Taylor contact in the Palmer area of Ellis County. Reaser (1957) records the same species, one form 35 inches in diameter, in the uppermost Austin in Dallas County. In Collin County, *Parapuzosia* has been found at Wylie, within 10 feet of the "lithologic contact" between the Austin and Taylor and north of Lucas several specimens, one 36 inches in diameter, have been found just a few feet below the Austin-Taylor contact. These occurrences

document the position of *Parapuzosia* in the uppermost Austin over several thousand square miles in three North Texas counties. There are other species of this genus at different stratigraphic positions in the Austin including *Parapuzosia* aff. *stobaei* reported by Adkins & Lozo (1951) from the lower part of the Austin near Waco, and other smaller species presently being studied by Keith Young (personal communication, 1958).

PARAPUZOSIA (AUSTINICERAS)

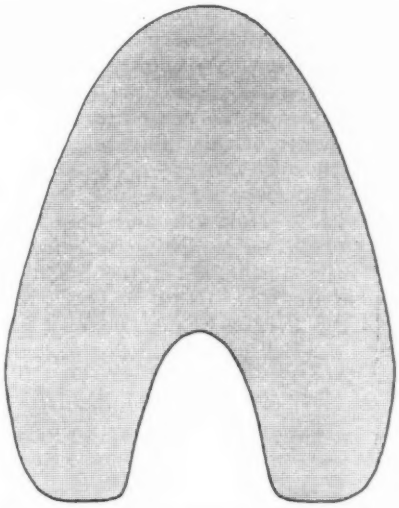
In 1949 Adkins reported an "*Austiniceras* n. sp." from the limestone flags about 300 feet below the Austin-Eagle Ford contact in Travis County, Texas, and an *Austiniceras* sp. from the uppermost Eagle Ford of Watters Park in the Austin area. Neither was described.

About 1940, Mr. W. Q. Seale of Dallas found a large well preserved specimen, identified here as *Austiniceras*, in the upper Britton member of the Eagle Ford about one and a half miles southeast of Britton, Texas. The specimen shows an excellent suture pattern but portions of the ribbing are not present. This specimen is the first *Austiniceras* to be described from Texas. Anderson (1958) reports *Austiniceras* from California but there is question as to the validity of his identifications. The fragments reported by Adkins (1949) and the specimen described in this report are from Upper Turonian rocks.

SYSTEMATIC PALEONTOLOGY

Family DESMOCERATIDAE Zittell, 1895
Subfamily PUZOSIINAE Spath, 1922
Genus PARAPUZOSIA Nowak, 1913
Subgenus AUSTINICERAS Spath, 1922
Type species: *Ammonites austeni* Sharpe.

Matsumoto (1954) has discussed the history of *Austiniceras* in some detail. He recognized that *Austiniceras* and *Parapuzosia* may have only subgeneric difference and this is recognized according to the present definition (Arkell, Kummel & Wright, 1957). One of the most important criteria for distinguishing the two subgenera is by the whorl shape, convergent and narrow in *P.* (*Austiniceras*) and oval in *P.* (*Parapuzosia*). The size and shape of the ribs are of course significant, but when only the septate portions of shells are preserved the whorl section is usually diagnostic.



TEXT-FIG. 2—Whorl section of *P.* (*Austiniceras*) *sealei*, n. sp., at 600 mm., ×¼.

PARAPUZOSIA (AUSTINICERAS) SEALEI
Clark, n. sp.
Pl. 34, figs. 1–3

Large phragmocone, no body chamber, greatest diameter of 600 mm. Umbilicus large and 180 mm. diameter at greatest diameter of specimen. Height of last whorl is 250 mm., width 180 mm. Umbilical wall is 40 mm. at the maximum diameter. There are four whorls shown by the wide umbilicus. Some of ribbing removed exposing excellent sutures of the general Puzosiinae type (Text-fig. 1). *A. sealei*, n. sp. is distinguished by its extremely narrow convergent whorl section and sinuous forward projecting ribs which are closely spaced and of equal size. These features distinguish it from *A. austeni* (Sharpe) whose whorl section has a dorsal bulge and from other species of *Austiniceras*.

Discussion.—Differentiation into major and minor ribs normally occurs on the outermost whorls of *Austiniceras*, not present on the holotype of *A. sealei*, n. sp. The extremely narrow whorl section (Text-fig. 2) up to diameter of 600 mm. separates this species from other *Parapuzosia* and

other species of *Austiniceras*. Specimen is an internal mold with shell material adheri g. It is bright brownish-yellow color and the cobalt nitrate test shows the composition to be calcite and not aragonite. The minimum diameter of this individual at death was a little over three feet, assuming that only the body chamber is missing.

Occurrence.—Holotype and only known specimen collected by W. Q. Seale from the upper Britton member of the Eagle Ford (Upper Turonian), about 50 yards to the side of the Britton-Cedar Hill road about one and one half miles southeast of Britton, Dallas County, Texas.

Repository.—Southern Methodist University, Paleontology Museum, 35024.

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THE AMERICAN UPPER ORDOVICIAN STANDARD III. CONODONTS FROM THE FAIRVIEW AND McMILLAN FORMATIONS OF OHIO, KENTUCKY AND INDIANA

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ABSTRACT—The Fairview and McMillan formations of the Cincinnati region, the reference standard for the North American Maysville Stage (Upper Ordovician), have yielded a large collection of conodont-elements, referable to 29 species, distributed among 18 genera. Fourteen species are known to range through the Eden, Fairview, and McMillan formations; most of these are represented as well in late Mohawkian and Trentonian strata in the midcontinent province of North America, and several continue into the Richmond group. Three species in the Fairview fauna occur also in the Eden, but do not range above the Fairview locally; seven species are restricted to the Fairview. Four species, introduced locally in late Eden or early Fairview strata, continue into the McMillan, which otherwise contains a reduced fauna of long-ranging midcontinent species. The presence of *Ambalodus*, *Amorphognathus*, and *Belodina* in Eden and Fairview strata, but not above them, suggests that the Orchard Creek shale of Missouri, the pre-upper Brainard Maquoketa shale of Iowa, and the Maravillas formation of Texas (which have all yielded representatives of these genera) are Maysville in age, or older. Four species (*Eoligonodina fairmountensis*, *Oulodus casteri*, *Prioniodina velicuspis*, and *Zygognathus maysvillensis*) are described for the first time.

INTRODUCTION

THIS report, which deals with conodonts from the Fairview and McMillan formations, is the third contribution in a series designed ultimately to provide detailed descriptions and interpretations of the strata and fossil faunas of the reference standard of the Upper Ordovician Cincinnatian Series in southwestern Ohio and adjacent parts of Kentucky and Indiana. A study of the morphology and stratigraphic sequence of conodonts in the Richmond group of Kentucky and Indiana was published in 1951 by Branson, Mehl, & Branson, and a similar study of the conodont fauna of the Eden formation was presented by Sweet, Turco, Warner, & Wilkie in 1959. The present report, therefore, may be considered to complete the elucidation of ranges, morphology, and local distribution of conodonts within the reference standard of the Cincinnatian Series.

The illustrations that accompany our report were made possible through the generosity of the Graduate School of The Ohio State University. We have profited from discussion of stratigraphic and paleontologic problems with Professors Malcolm P. Weiss and Mildred F. Marple, of The Ohio State University, and Professors Kenneth E. Caster and William F. Jenks, of the University of Cincinnati. A contribution toward completion of the manuscript was made from the "Friends of Orton Hall" fund.

STRATIGRAPHY

Bassler (1906) recognized nine formational units in the type section of the Upper Ordovician Cincinnatian Series; from oldest to youngest, these are the Utica, Eden, Fairview, McMillan, Arnheim, Waynesville, Liberty, Whitewater, and Saluda formations. The Utica, Eden, Fairview, and McMillan formations constitute Bassler's Covington group, whereas the Arnheim through Saluda formations were included in the Richmond group. The current practice is to include the "Utica" (Fulton beds) with the Eden formation, the standard for an early Cincinnatian Eden Stage. The Fairview and McMillan formations together constitute the reference standard for a medial Cincinnatian Maysville Stage, whereas the Arnheim through the later named Elkhorn formations are considered the standard for the late Cincinnatian Richmond Stage.

The Fairview formation, named by Bassler (1906) for exposures near Fairview Heights, Cincinnati, has been divided into two members, in ascending order, the Mount Hope and Fairmount (Nickles, 1902). These units were originally distinguished by their contained bryozoan faunas, the Mount Hope being the "*Amplexopora septosa* beds" and the Fairmount the "*Dekayia aspera* beds." The Mount Hope was named for an exposure on Mount Hope, at Cincinnati; the Fairmount was named for Fairmount, a part of Cincinnati, Ohio (Nickles, 1902).

The Fairview formation consists of 100 to 120 feet of thin, alternating beds of bluish gray, fossiliferous limestone and greenish gray shale. Individual beds are both laterally and vertically gradational and a number of different structural types of both limestone and shale occur within the formation. In general, however, shale beds are thicker and limestone beds correspondingly thinner in the lower 50 to 60 feet of the formation than in the upper 60 to 70 feet. As a result, the formation can be crudely subdivided into two members, of about the same thickness, which correspond roughly, at least in the type section, to Nickles' (1902) Mount Hope and Fairmount divisions. These "divisions" were based, however, on variations in the abundance of certain bryozoan species in the section at Cincinnati—variations that may well occur at different levels in other sections, or may even involve different species. For this reason, Bassler (1906) pointed out that it would be wise to regard all the strata in Nickles' Mount Hope and Fairmount as part of a single formation, for which he proposed the name Fairview. Insofar as possible, the writers have paid relatively less attention to the discrimination of the gradational boundary between the Mount Hope and Fairmount than to defining the upper and lower contacts of the Fairview formation as a whole. By and large, the more calcareous upper Fairview has been assigned to the Fairmount, whereas the shalier lower Fairview has been regarded as Mount Hope. In sections in which this interval is well exposed, the level of the first appearance of *Strophomena planoconvexa* was considered to mark the boundary between the two members, even though it is realized that this horizon may not always be at the same level, even in adjacent sections.

The McMicken, or upper member of the Eden formation, resembles the Mount Hope member in lithologic and structural characteristics. In general, however, shale beds are thicker and limestone beds correspondingly thinner in the McMicken than in the Mount Hope. The upper portion of the McMicken member contains three or four closely spaced limestones containing abundant *Resserella* (=*?Onniella*); the uppermost of these marks the boundary between the Eden and Fairview formations (Caster, Dalvé & Pope, 1955).

The lower McMillan Bellevue member differs, in general, from the Fairmount in structure and in its topographic expression. The Bellevue is characterized by the abundance of thin, irregular, nodular, argillaceous limestones with *Platystrophia* and *Hebertella*, separated by very thin shale lenses. The member is very resistant to sapping and slope retreat; as a result, it tends to form sheer cliffs and to cause local steepening of stream gradients. Thin beds of Bellevue aspect (but lacking *Platystrophia* and *Hebertella*) first appear in the Mount Hope, and thicker units of the same type are found in the Fairmount in some sections. Consequently, it is difficult to attach too much significance to lithology in separating the Fairmount from the Bellevue. The thin, "rubbly" units that appear in the Fairview formation contain abundant *Rafinesquina alternata* but are almost devoid of *Platystrophia ponderosa* and *Rafinesquina fracta*, forms that are abundant in the Bellevue. Such a distinction, based in large part on fossils, was used to separate the Fairview and McMillan, even though it is clear that the two formations are vertically gradational. The contact was similarly placed in Hamilton County by Hyde (1959) who excluded from the Bellevue the "rubbly" zones intercalated in the upper part of the Fairview. It should be noted, however, that both Desjardins (1934) and Forsyth

(1946) included these thin "rubbly" zones in the Bellevue.

Megafossils are abundant in the type section of the Cincinnatian Series and many thin biostratigraphic and rock divisions have been based on their occurrence. This study does not deal with megafossils; however, in order properly to distinguish formational boundaries, it is necessary to be familiar with at least the common forms.

Bryozoans are the most abundant fossils and were first used in subdividing the type Cincinnatian. Because of the fact that many bryozoan species exhibit a variety of external forms under differing ecologic conditions, however, accurate identification is possible only from a study of thin sections. This fact reduces the field utility of bryozoans and makes necessary the use of other fossils in determining formational boundaries.

The brachiopods *Thaerodonta rugosa* and *Resserella* (=*?Onniella*) *multisecta* are found commonly in the closely spaced limestones at the top of the Eden; *Thaerodonta* is apparently absent in the Fairview (although it "recurs" in the Richmond). *Resserella* (=*?Onniella*) occurs throughout the Mount Hope and Fairmount, but is not as abundant as in the Eden. McMicken bryozoan species *Dekayia ulrichi*, *Batostoma jamesi*, and *Hallopora oneilli* apparently do not continue into the Fairmount, although the genera to which they belong are long-ranging. The trilobites *Flexicalymene granulosa* and *F. meeki* are more common in the McMicken than in the Mount Hope. *Cryptolithus tesselatus* is not uncommon in the Eden but is rare in the Fairview (Caster, Dalvé & Pope, 1955). The writers did not collect this species from any section. *Climacograptus typicalis* is found in "patches" on Mount Hope mudstones; no graptolites were noted in the Fairmount, but they occur in the Eden.

Fossils common in the Fairview formation are the brachiopods *Platystrophia hopensis* (characteristic of the Mount Hope), *Zygospira cincinnatiensis* and *Platystrophia laticosta*. *Strophomena planoconvexa* is particularly abundant near the base of the Fairmount. The bryozoans *Escharopora falciformis*, *Constellaria florida*, *Hallopora dalei* and *Dekayia aspera* are common in the Fairview and the gastropod *Cyclonema gracile* is common in some sections and appears to be quite distinctive of the Mount Hope. *Cyclonema inflatum* and *Clathrospira conica* are found in some abundance in the Fairmount.

The McMillan formation was named by Bassler (1906) and includes, as members, Nickles' Bellevue (or *Monticulipora molesta*), Corryville (or *Chiloporella nicholsoni*), and Mt. Auburn (or *Platystrophia lynx*) beds. At and near Cincinnati, the McMillan formation is about 90 feet thick and the three members into which Nickles divided it are distinctive lithologically as well as faunally.

The Bellevue is distinguished from the subjacent Fairmount in most sections by the greatly increased abundance in it of the brachiopods *Platystrophia ponderosa*, *Rafinesquina fracta*, and *Hebertella sinuata*, all three of which, however, occur in the upper Fairview. In the Bellevue, these forms occur in layers in the closely spaced limestones and thin shales, and are, in large part, responsible for the "rubbly" appearance of these beds. Bryozoa are abundant in the Bellevue, and Bellevue brachiopods are thick-shelled and massive.

The Corryville member is composed for the most part of rather evenly bedded, in part ripple-marked limestones, and shale, both of which are abundantly fossiliferous and fairly persistent laterally. The Mt. Auburn member, the youngest McMillan division, is thin rubbly calcareous mudstones in which *Platystrophia ponderosa* and *Hebertella* are conspicuous by their exceptional abundance. Presumably, both the Bellevue and Mt. Auburn members were deposited in shallow, agitated water, whereas the Corryville seems to have formed under somewhat quieter conditions.

Fairview and McMillan microfossils consist mostly of conodonts, but many ostracodes and scolecodonts were noted in some samples, and great numbers of well preserved juvenile gastropods, brachiopods, and pelecypods occur throughout the formations.

The Covington formations and members defined at Cincinnati become increasingly less distinctive to the southeast. Near Maysville, Kentucky, for example, the limestone: shale ratio seems considerably greater than at Georgetown, Ohio (section 14807) and the "faunal zones" that characterize the Eden and Fairview formations at Cincinnati seem not to be so well defined. *Platystrophia hopensis* and *Escharopora falciformis* occur with *Thaerodonta* in rocks of Eden aspect at Maysville and the correlation between the megafossil sequence is otherwise not the same as at Cincinnati. Magorian (1954) states that the Mount Hope corresponds to the early evolution of *Platystrophia* at Cincinnati, whereas beds of McMicken age in the Cincinnati region contain the "earliest" *Platystrophia*.

For many of the same reasons, subdivision of the McMillan formation east of Cincinnati into lithologic units that correspond in sequence and faunal characters to those at Cincinnati is not always easy, particularly near the periphery of the Cincinnati "inlier." That is, in some places the bottom

(*Text continued on next page*)

EXPLANATION OF PLATE 35

Figures drawn from photographs of specimens from the Fairview formation. All ×50.

FIG. *1,8—Oistodus abundans* Branson & Mehl. Outer and inner lateral views. Fairmount member, locality 14810. OSU 22841, 22842.

2,7—Drepanodus suberectus (Branson & Mehl). Inner and outer lateral views. Mount Hope member, locality 14808. OSU 22837, 22838.

3,6—Panderodus gracilis (Branson & Mehl). Outer and inner lateral views. Mount Hope member, locality 14814. OSU 22853, 22854.

4,13—Drepanodus homocurvatus Lindström. Lateral views. Fairmount member, locality 14812. OSU 22835, 22836.

5—Panderodus robustus (Branson, Mehl & Branson). Lateral view. Mount Hope member, locality 14808. OSU 22852.

9,14—Dichognathus brevis Branson & Mehl. Inner and outer lateral views. Mount Hope member, locality 14808. OSU 22831, 22832.

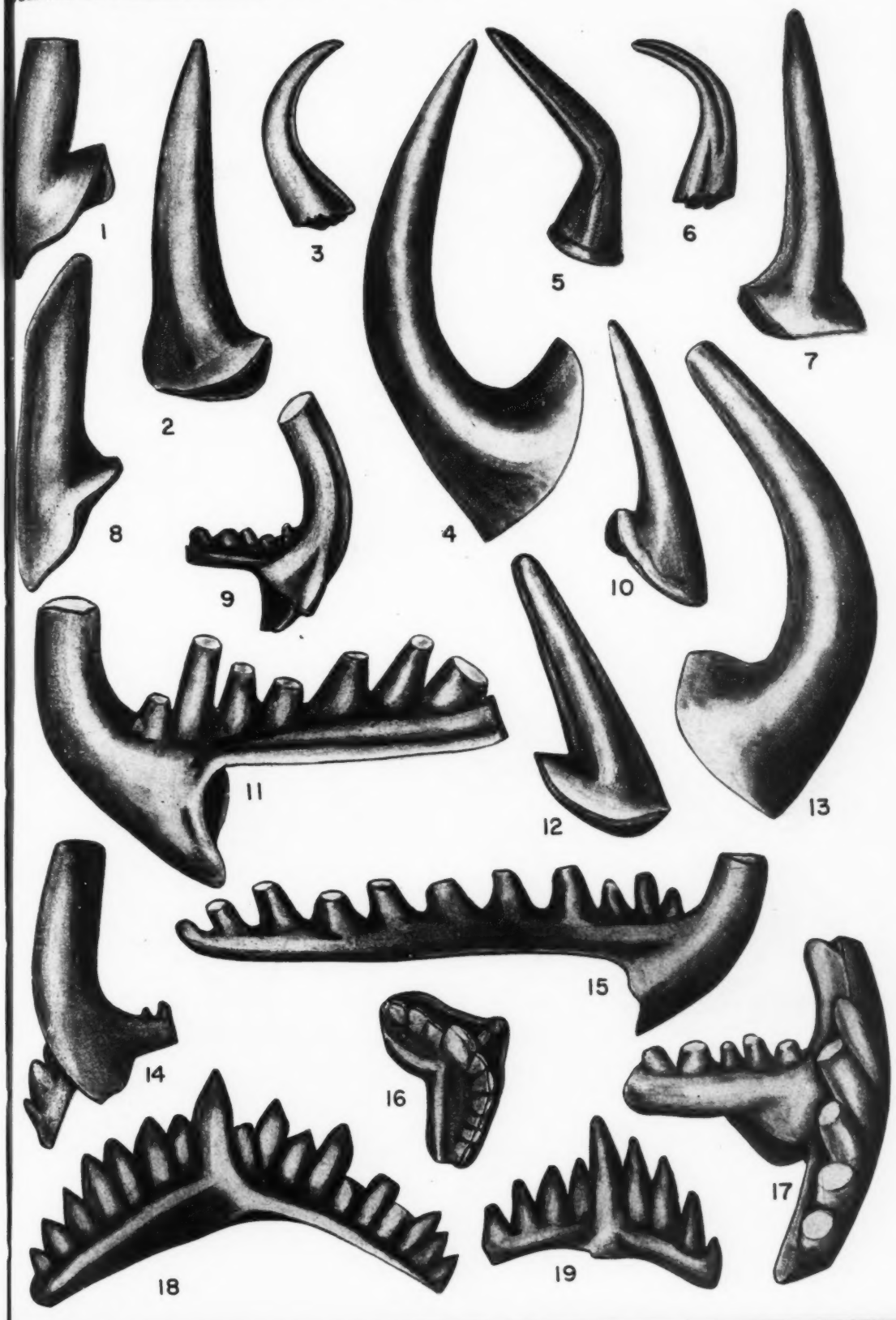
10,12—Oistodus inclinatus Branson & Mehl. Outer and inner lateral views. Fairmount member, locality 14808. OSU 22843, 22844.

11,15—Cordylodus excavatus Sweet, Turco, Warner & Wilkie. Outer and inner lateral views. Mount Hope member, locality 14808. OSU 22827, 22828.

16—Ambalodus triangularis Branson & Mehl. Superior view. Mount Hope member, locality 14814. OSU 22820.

17—Eoligonodina fairmountensis Pulse & Sweet, n. sp. Inner lateral view. Fairmount member, locality 14810. OSU 22839.

18,19—Ozarkodina robusta Stauffer. Outer and inner lateral views (fig. 19 of a juvenile). Fairmount member, locality 14814. OSU 22850, 22875.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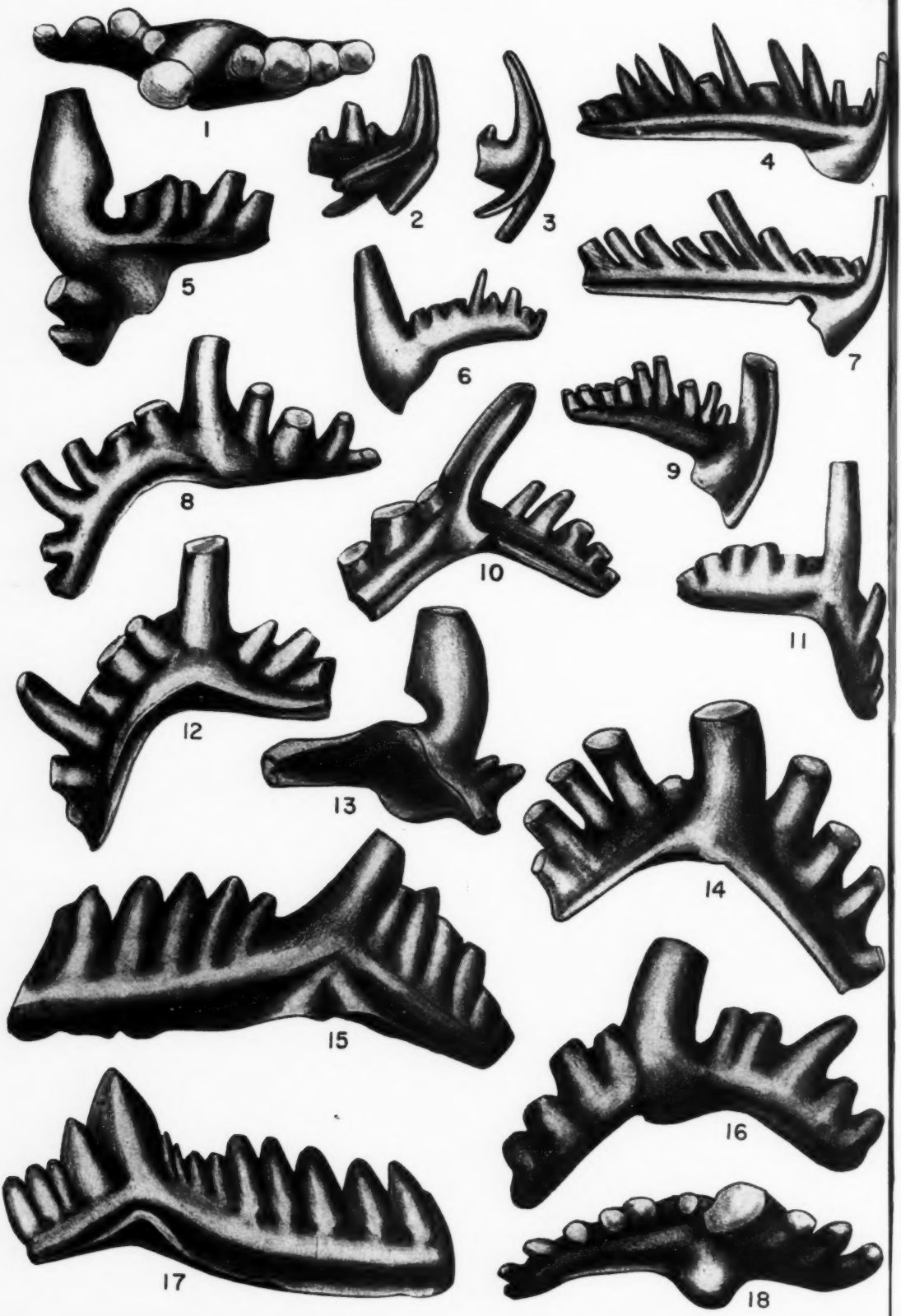
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seems to have been agitated throughout McMillan time and the typical Corryville facies does not seem to have been developed —rubbly mudstones and shingled *Rafinesquina* layers occur throughout the McMillan. In other places, either the Bellevue or the Mt. Auburn, or both, are much thicker than at Cincinnati and the intervening Corryville much reduced in thickness. Not surprisingly, benthonic forms apparently adapted to the agitated conditions represented by the Bellevue and Mt. Auburn facies occur throughout the McMillan in those places where the bottom was agitated throughout the time of accumulation of the formation.

In connection with this study, conodont-elements were collected from the upper two-thirds of an exposed section (14805) at Maysville, Kentucky. The sequence is anomalous both lithologically and faunally, but seems to indicate either that rocks of Fairview aspect are younger at Maysville than the typical Fairview or that the McMillan is much increased in thickness. Furthermore, the conodont fauna characteristic of the Fairview in all other sections studied seems to range into strata of McMillan aspect at Maysville. The writers feel that it is not possible at this time to subdivide the Maysville, Kentucky, section into lithologic units that correspond precisely either in sequence or in age to those at Cincinnati. Presumably, however, when

(*Text continued on next page*)

EXPLANATION OF PLATE 36

Figures drawn from photographs of specimens from the Fairview formation.

FIG. *1,8,12—Oulodus casteri* Pulse & Sweet, n. sp. Superior, anterior, and posterior views, ×50. Fairmount member, locality 14811. OSU 22845, 22846, 22847.

2—Tetraprioniodus superbus (Rhodes). Lateral view, ×100. Mount Hope member, locality 14808. OSU 22876.

3—Keislognathus gracilis Rhodes. Lateral view, ×50. Mount Hope member, locality 14808. OSU 22840.

4,7—Cordylodus delicatus Branson & Mehl. Inner and outer lateral views, ×50. Mount Hope member, locality 14808. OSU 22825, 22826.

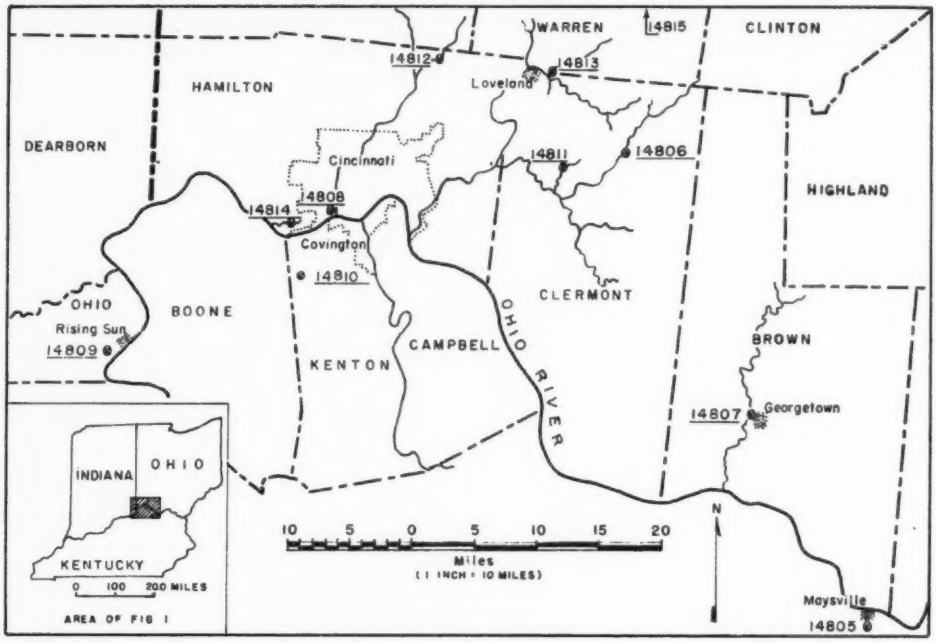
5,13—Prioniodina velicuspis Pulse & Sweet, n. sp. Outer and inner lateral views of the cotypes, ×50. Fairmount member, locality 14808. OSU 22863, 22864.

6,9—Cordylodus flexuosus (Branson & Mehl). Outer and inner lateral views, ×50. Mount Hope member, locality 14808. OSU 22829, 22830.

10,11—Prioniodina delecta (Stauffer). Inner and outer lateral views, X50. Mount Hope member, locality 14808. OSU 22859, 22860.

14,16,18—Prioniodina rotunda Sweet, Turco, Warner & Wilkie. Inner lateral, outer lateral, and superior views, ×50. Fairmount member, locality 14808. OSU 22861, 22862, 22877.

15,17—Aphelognathus irregularis Pulse & Sweet, n. sp. Outer and inner lateral views, ×50. Fairmount member, locality 14808. OSU 22848, 22849.



TEXT-FIG. *1*—Outline map of Cincinnati region, Ohio, Kentucky, and Indiana, showing Fairview and McMillan conodont localities.

the micro- and megafaunas have been completely studied, their distribution will make temporal correlations possible, even though the characteristic Cincinnati formations may not be recognizable.

CONODONT LOCALITIES

Conodonts described in this report were collected from Fairview and McMillan strata measured and sampled at the following localities (Text-fig. 1). Measured sections are on file with the Ohio Division of Geological Survey, The Ohio State University, Columbus. Locality numbers are O.G.S. file, or section numbers.

Locality 14805.—Road cut, U. S. Hwy. 62–68, 1.5 miles southwest of Maysville, Mason County, Kentucky. Measured section includes at least 197 feet of Covington strata. The lithologic and faunal sequences here differ from those at Cincinnâti and the writers are uncertain as to correlation of various parts of the section.

Locality 14806.—Stonelick Creek, about 3 miles north of Owensville, Stonelick Township, Clermont County, Ohio (Batavia, Ohio, quadrangle). The upper Mount Hope, Fairmount, Bellevue, Corryville, and Mount Auburn members are exposed here. Section of Fairview and McMillan formations 154 feet thick; subdivided into 144 sampled units.

Locality 14807.—White Oak Creek, 0.75 mile west of Georgetown, Lewis Township, Brown County, Ohio (Higginsport, Ohio, quadrangle). Complete section of Fairview formation and partial section of Bellevue member of McMillan formation measured and collected. One hundred fifty-four feet of strata measured; divided into 100 sampled units.

Locality 14808.—Cleveland Wrecking Company storage lot on Bald Knob, 0.5 mile southwest of junction of Western Hills viaduct and State Avenue, Cincinnati, Ohio (West Cincinnati, Ohio, quadrangle).

Complete section of Fairview formation sampled here; section 112 feet thick, divided into 50 units.

Locality 14809.—Road cut, U. S. Hwy. 56, 3.0 miles southwest of Rising Sun, Ohio County, Indiana (Aberdeen, Ky.–Ind., quadrangle). Upper McMicken member, Eden formation, Fairview formation, Bellevue, Corryville, and incomplete Mount Auburn members of the McMillan formation exposed here; 92 feet of strata measured and 65 units sampled.

Locality 14810.—Bullock Pen and Rice creeks, Narrows Road-Turkeyfoot Road intersection, 2.0 miles southeast of Erlanger, Kenton County, Kentucky (Independence, Kentucky, quadrangle). Incomplete section of Mount Hope member, complete section of Fairmount member of Fairview formation. Sixty-three feet of exposed section; 48 units sampled.

Locality 14811.—Dry Run, 1.0 mile north of U. S. Route 50, 4.5 miles southeast of Milford, Stonelick Township, Clermont County, Ohio (Batavia, Ohio, quadrangle). Incomplete section of Mount Hope and Fairmount members of Fairview formation; 90 feet of strata measured, divided into 40 sampled units.

Locality 14812.—Sharon Run, Sharon Woods (Hamilton County public park), 0.5 mile northeast of Sharonville, Sycamore Township, Hamilton County, Ohio (Mason, Ohio, quadrangle). Seventy-one feet of Fairview formation exposed; divided into 50 sampled units.

Locality 14813.—Grog Run, 3.2 miles east of Loveland, Goshen-Hamilton townships, Clermont-Warren counties (Morrow, Ohio, quadrangle). Incomplete section of Fairview formation; complete Mount Hope member, incomplete Fairmount member. Sixty-two feet of strata exposed, divided into 35 sampled units.

Locality 14814.—Rapid Run, 2.5 miles northeast of Delhi, Delhi Township, Hamilton County, Ohio (West Cincinnati, Ohio, quadrangle). Complete section of Mount Hope member, incomplete section of Fairmount member. One hundred and nine feet of strata exposed, divided into 62 sampled units.

Locality 14815.—Camp Kern Run, 0.3 mile west of Ft. Ancient, Washington Township, Warren County, Ohio (Morrow, Ohio, quadrangle). Some 30 feet of the Corryville and 15 feet of the Mount Auburn member, McMillan formation, are exposed (in addition to superjacent Arnheim and Waynesville strata which were not measured). Section divided into 30 units, each of which was sampled.

DISTRIBUTION AND STRATIGRAPHIC SIGNIFICANCE OF FAIRVIEW AND McMILLAN CONODONTS

Altogether, the writers have collected about 10,000 identifiable conodont-elements from the Fairview and McMillan formations at the places indicated in Text-figure 1. These conodont-elements are referable to 29 species, distributed among 18 genera, and, in aggregate, they are thought to be a reasonably representative sample of the Fairview and McMillan conodont faunas. The vertical distribution locally of known Fairview and McMillan species is shown in Table 1.

Representatives of 14 species (*Cordylodus delicatus, C. flexuosus, Dichognathus brevis, D. typica, Drepanodus homocurvatus, D. suberectus, Oistodus abundans, O. inclinatus, Ozarkodina robusta, Panderodus gracilis, Phragmodus undatus, Trichonodella angulata, T. subundulata,* and *Zygognathus deformis*) account for about 69 percent of the total number of Fairview conodont-elements in the collections at hand, and the same group of species occurs with about this frequency in every sampled unit at every locality studied. For this reason, it seems logical to conclude that some 69 percent of the total Fairview conodont fauna was composed of these species. With the exception of *Trichonodella angulata* and *T. subundulata*, which are not yet known from rocks older than the Eden formation of Ohio and Kentucky, all the species just listed are long-ranging Ordovician forms in the North American midcontinent province. A majority of them are first recognized in rocks of early Wilderness age, and they range through the Trenton, Eden, and Maysville

TABLE 1—STRATIGRAPHIC DISTRIBUTION OF FAIRVIEW AND MCMILLAN CONODONT SPECIES

Conodont species	Eden formation	Fairview formation		McMillan formation
		Mount Hope member	Fairmount member	
Ambalodus triangularis B. & M.				
Keislognathus gracilis Rhodes				
Amorphognathus ordovicica B. & M.	?			
Belodina inclinata (B. & M.)				
Cordylodus excavatus S., T., W., & W.				
Prioniodina rotunda S., T., W., & W.				
Tetraprioniodus superbus (Rhodes)				
Eoligonodina fairmountensis, n. sp.				
Oulodus casteri, n. sp.				?
Prioniodina velicuspis, n. sp.				
Prioniodina delecta (Stauffer)				
Trichonodella tenuis (B. & M.)				
Panderodus robustus (B., M., & B.)				
Aphelognathus irregularis, n. sp.				
Zygognathus maysvillensis, n. sp.				
Cordylodus delicatus B. & M.				
Cordylodus flexuosus (B. & M.)				
Dichognathus brevis B. & M.				
Dichognathus typica B. & M.				
Drepanodus homocurvatus Lindström				
Drepanodus suberectus (B. & M.)				
Oistodus abundans B. & M.				
Oistodus inclinatus B. & M.				
Ozarkodina robusta Stauffer				
Panderodus gracilis (B. & M.)				
Phragmodus undatus B. & M.				
Trichonodella angulata S., T., W., & W.				
Trichonodella subundulata S., T., W., & W.				
Zygognathus deformis (Stauffer)				

stages. A few (*e.g.*, *Drepanodus homocurvatus*) continue through the Richmond Stage. As a consequence, these species, although abundantly represented in every Fairview sample studied, have little stratigraphic significance. It should be noted, however, that only a few of these species have been reported from rocks supposed to be of Wilderness-Richmond age in the Anglo-Scandinavian or Appalachian provinces. Only a few conodonts are known from Ordovician rocks in the Appalachian province of North America, and these appear to represent a conodont fauna markedly unlike the Middle and early Upper Ordovician fauna of the midcontinent. This group of ubiquitous species seems, then, to be of significance as an indicator of a general faunal realm, the midcontinent province. These species provide the "background" against which more significant faunal changes took place.

Four Fairview species (*Amorphognathus ordovicica*, *Belodina inclinata?*, *Keislognathus gracilis*, and *Ambalodus triangularis*), representing only about two percent of the total number of conodont-elements in Fairview collections at hand, and confined for the most part to the lower part of the Mount Hope member, are either direct continuations of species more abundant in the Eden formation and earlier rocks, or belong in genera well known from Eden strata, but in species new to the Cincinnati region. Only *Ambalodus triangularis* ranges through the Fairview and it is not common in the Fairmount.

Amorphognathus ordovicica, the type of *Amorphognathus*, was first described from the Orchard Creek shale of Missouri (Branson & Mehl, 1933). Subsequently, representatives of this species have been reported (Graves & Ellison, 1941) from the Maravillas formation of the Marathon Basin, Texas, from the upper part of the Bighorn formation of Wyoming (Stone & Furnish, 1959), and from the Keisley limestone of Westmorland, England (Rhodes, 1955). Conodonts from the Gelli-grin and Pen-y-garnedd limestones of Wales, referred to this species by Rhodes in 1953, are perhaps also valid representatives of *A. ordovicica*, but they are unlike the type in several respects.

If *Polyplacognathus* Stauffer is, indeed, a synonym of *Amorphognathus* Branson & Mehl, as most writers consider it to be, then *Amorphognathus* has an extended range in Middle and early Upper Ordovician rocks in both Europe and North America. However, the few species of *Amorphognathus* described from the Middle Ordovician of North America have longitudinally carinate under surfaces and thereby resemble the types of *Polyplacognathus*, whereas early Upper Ordovician forms from North America and Middle and Upper Ordovician forms from Europe have excavated under sides and resemble the type of *Amorphognathus*. It may well be, then, that *Amorphognathus* is a long-ranging Anglo-Scandinavian and Appalachian genus that, with other forms, invaded the midcontinent province in early Upper Ordovician time, and that the Middle Ordovician counterpart of *Amorphognathus* in the midcontinent was *Polyplacognathus*, which disappeared by the end of the Trentonian. Regardless of this possibility, however, *Amorphognathus ordovicica* itself differs considerably from forms known from Edenian and presumably contemporaneous deposits in Wales, and the writers suspect that this distinctive species defines a restricted zone in the Upper Ordovician of North America (and possibly Europe).

The genus *Belodina* includes a number of species in the Middle and early Upper Ordovician of the North American midcontinent province and may well be regarded as typical of that province. The genus first appears in the Decorah shale of the Upper Mississippi Valley and equivalent strata in Missouri and ranges with decreasing abundance only as high as the lower part of the Mount Hope member of the Fairview in the Cincinnati region. Even though *Belodina* has an extended stratigraphic range, we have accorded its presence in the lower Fairview and its apparent absence in younger rocks considerable importance. That is, it seems reasonable at this time to consider all strata with *Belodina* as older than the upper part of the Fairview formation. Such an interpretation is supported by the known stratigraphic ranges of other conodont genera and species. *Belodina inclinata*, with which our Fairview forms are provisionally associated, has been reported previously only from the Orchard Creek shale of Missouri.

Keislognathus was erected by Rhodes (1955) for conodont-elements from the early Ashgillian Keisley limestone of Westmorland, England, and a few representatives of the genus have subsequently been reported from the Stewartville and Dubuque members of the Galena formation in Iowa (Ethington, 1959), the early Eden of Ohio and Kentucky (Sweet, *et al.*, 1959), and doubtfully from the upper part of the Bighorn formation of Wyoming (Stone & Furnish, 1959). Several specimens of *K. gracilis*, the type species, have been recovered from the basal few feet of the Mount Hope member of the Fairview formation. The known range of *Keislognathus* in North America seems to be from early Edenian (or possibly late Trentonian) into the early Maysvillian, and the occurrence of representatives of the genus through this interval may indicate that conditions permitting Anglo-Scandinavian conodonts to migrate into the midcontinent persisted from the early Eden into the early Maysville.

Ambalodus triangularis is a distinctive species of a long-ranging Anglo-Scandinavian-Appalachian genus which has been reported from early Upper Ordovician rocks in both Europe and North America. In the Cincinnati region, the species is most abundant in the Eden and early Fairview (Mount Hope) formations. A single specimen, however, is known from the upper Fairview (Fairmount member). In the midcontinent. *A. triangularis* is known from the Orchard Creek shale of Missouri, the Stewartville and Dubuque members of the Galena, and the phosphatic member of the Maquoketa formation of Iowa, the Maravillas of Texas, and the upper part of the Bighorn formation of Wyoming. It is logical, then, to conclude that all of these strata were deposited during the same interval of time in which the Eden and Fairview formations were laid down.

Like *Ambalodus*, *Tetraprioniodus* is a long-ranging Anglo-Scandinavian genus

known as yet in North America only from the upper Bighorn of Wyoming, the Dubuque member of the Galena formation of Iowa, and the basal Fairview of the Cincinnati region. Presumably, representatives of this genus invaded the midcontinent province with other European genera in the early Edenian and lingered through earliest Maysvillian time.

A group of five species (*Cordylodus excavatus, Eoligonodina fairmountensis, Oulodus casteri, Prioniodina rotunda, and P. velicuspis*) seems restricted in its development to the Fairview and has not been reported from other regions. Two of these species (*Cordylodus excavatus* and *Prioniodina rotunda*) appear for the first time, locally, at least, in rocks of late Edenian age. Representatives of these species, together with the other three (which appear at the base of the Fairview) account for about 22 percent of the total number of conodont-elements collected by the writers from the Fairview. By and large, these species include massive, robust conodont-elements of much greater than usual size. They are clearly related to smaller, somewhat more delicate species of the same genera and, for that reason, they may have only local, rather than regional stratigraphic significance. That is, the occurrence of this group of robust species in the Fairview of the Cincinnati region seems to define the formation paleontologically; however, neither this same group of species nor any group very much like it seem to occur elsewhere in rocks that, on other grounds, are the same age as the Fairview. This suggests that these species may be the local results of peculiar ecological conditions. Hence, even though this species-group is useful in defining the Fairview in the Cincinnati region, it may be of little help in interregional correlations.

About seven percent of the Fairview conodont-elements collected by the writers belong in species that, for the most part, appear first in the Mount Hope and range upward into the McMillan, or through it into the Richmond. Three of these species (*Aphelognathus irregularis, Panderodus robustus*, and *Zygognathus maysvillensis*) seem to be the forerunners of generic groups that are best known from the Richmond of Kentucky and Indiana, whereas two of them (*Prioniodina delecta* and *Trichonodella tenuis*) appear first in the late Edenian, range through the Fairview and McMillan, but are apparently not present in the Richmond. We attach no particular stratigraphic significance to the appearance of a few conodont-elements of Richmond aspect in the Fairview. However, this might indicate that the migration into the midcontinent of a faunal element that reached the climax of its development in the Richmond, began as early as Fairview time. Certainly, the presence of this group of species distinguishes the Fairview from the Eden, so, at least locally, and in combination with other Fairview conodonts, it is of stratigraphic utility.

Prioniodina delecta occurs sporadically throughout the Wilderness-Maysville interval in the midcontinent province. In the Cincinnati region it appears to be more common in the Fairview and McMillan formations than in the Eden. *Trichonodella tenuis* is known from the Orchard Creek shale of Missouri, the Maravillas formation of Texas, and the upper part of the Eden formation in Ohio and Kentucky. Such a distribution suggests that these units are not older than the upper part of the typical Eden, nor younger than the McMillan formation.

We are not able to recognize any significant differences between the conodont faunas of the Bellevue, Corryville, and Mount Auburn members of the McMillan formation and, taken as a whole, the McMillan conodont fauna is by far the least distinctive of the several we recognize in the reference standard of the Cincinnatian Series. Insofar as we are aware, not a single McMillan conodont species is restricted in occurrence to that formation and some 80 percent of the specimens in our McMillan conodont collections belong in species that range from early Wilderness into or through the Richmond. It should perhaps be noted the *Phragmodus undatus* and the several species of *Dichognathus* that account for such a large proportion of the Eden and

Fairview faunas (40% and about 20%, respectively) are much less abundant in the McMillan (10–12% of the collections), whereas representatives of *Cordylodus delicatus*, *C. flexuosus*, and *Ozarkodina robusta* seem to be relatively more abundant in McMillan than in subjacent strata. About 20 percent of our McMillan conodont-elements represent species introduced into the Cincinnati region in rocks of late Edenian or early Maysvillian age.

We regard the McMillan fauna as an indicator of the re-establishment in the Cincinnati region of the somewhat reduced, but nevertheless typical, long-ranging midcontinent fauna. This fauna was diluted and in part replaced by Anglo-Scandinavian-Appalachian forms in the Edenian and early Maysvillian (Fairview). In Fairview times, the character of the fauna was further modified by the migration into the Cincinnati region of, or the indigenous development of, a host of massive, distinctive species of otherwise typical midcontinent genera. Neither these massive species nor the Anglo-Scandinavian-Appalachian forms persist into the McMillan formation; hence its conodont fauna consists largely of the ubiquitous "background" species.

Complete sequences of Ordovician conodont faunas are known from only three places in the world, all in North America. In addition, however, faunas have been described (Rhodes, 1953, 1955; Lindström, 1954, 1955, 1957) from rather widely separated parts of the Ordovician System in Europe. Consequently, it is possible at this time to suggest correlation of Cincinnati units only with the three North American sections and with the Welsh and English sections studied by Rhodes.

In the Upper Mississippi Valley, a conodont fauna with Edenian species is known (Ethington, 1959) from the Stewartville and Dubuque members of the Galena formation and, perhaps, from the immediately overlying phosphatic member of the Maquoketa formation. Neither *Ambalodus* nor *Amorphognathus* continue above the phosphatic member of the Iowa Maquoketa, but species of *Belodina* are found as high as the Ft. Atkinson member of that formation (Glenister, 1957). Since *Belodina* ranges no higher than the Mount Hope member of the Fairview in the Cincinnati region, it seems reasonable to conclude that the Elgin, Clermont, and Ft. Atkinson members of the Iowa Maquoketa are either all equivalent to the Fairview, or are in part late Edenian and in part early Maysvillian in age. The Brainard shale contains only the long-ranging, ubiquitous midcontinent species, as does the McMillan of the Cincinnati area, hence the Brainard shale may be the Iowa equivalent of the McMillan. The Brainard limestone has yielded *Phragmodus* and a number of species of *Panderodus*, hence seems to be similar faunally to the early part of the Richmondian Arnheim formation of the Cincinnati area.

Conodonts from the Ordovician of Missouri formed the basis for Branson & Mehl's pioneer studies of North American conodont faunas; hence the sequence of conodonts is rather well known in southeastern Missouri. The Kimmswick limestone of Missouri is clearly Middle Ordovician in age. It is unconformably overlain by the Cape limestone, which, in turn, is overlain by the Orchard Creek shale (including the Thebes sandstone member). The latter contains conodont-elements strikingly similar to those now known to occur in the upper part of the Eden, and the Fairview formations of the Cincinnati region. *Ambalodus*, *Amorphognathus*, *Belodina*, and *Trichonodella tenuis* are all found in the Orchard Creek, particularly in the Thebes sandstone member. The first three of these are represented by the same species in the Fairview, and the genera themselves are not known above the Fairview of the Cincinnati region. Presumably, then, the Orchard Creek shale is of the same general age as the late Eden (McMicken member) and Fairview formations.

A conodont fauna similar to that of the Orchard Creek and McMicken-Fairview has been reported by Graves & Ellison (1941) from the Maravillas formation of Texas. Graves & Ellison point out the similarity between the Maravillas conodont fauna and that of the Orchard Creek ("Maquoketa"), and the writers agree that they are of essentially the same age. Fur-

thermore, we believe that both the Maravillas and Orchard Creek are of late Edenian and early Maysvillian age.

Ethington & Furnish (1959) have recently described a small collection of conodont-elements from the Shamattawa limestone along the Knife River, west of Hudson Bay. The conodont-elements they describe are strikingly similar in aggregate to those in the much larger collections we have assembled from the typical Fairview formation. The Shamattawa collection lacks *Ambalodus* and *Amorphognathus*, genera that are represented in our large Fairview collections by only a few specimens. Furthermore, the Shamattawa contains *Belodina*, a genus that is not found locally, at least, above the Mount Hope member of the Fairview. For these reasons, it seems to us that the Shamattawa and Fairview formations are probably of about the same age.

European and American conodont faunas are not very much alike. However, during early Upper Ordovician time, there seems to have been a migration of a few European forms. (*Ambalodus*, *?Amorphognathus*, *Keislognathus*, *Tetraprioniodus*, and others) into the midcontinent province of North America. This migration brought with it several distinctive species, representatives of which have been found in Edenian and early Maysvillian strata in North America and in late Caradocian and early Ashgillian rocks in the United Kingdom. This certainly suggests that the Eden and Fairview formations are at least broadly equivalent to strata in the zones of *Pleurograptus linearis* and *Dicellograptus complanatus*, from which many of the same, or similar, conodont species have been reported.

SYSTEMATIC DESCRIPTIONS

Genus AMBALODUS Branson & Mehl, 1933

Type species: *Ambalodus triangularis* Branson & Mehl, 1933.

AMBALODUS TRIANGULARIS Branson & Mehl

Pl. 35 fig. 16

Ambalodus triangularis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 127,128, pl. 10, figs. 35–37; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 26; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 280, pl. 20, figs. 28–31; ——, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 122,123, pl. 7, figs. 9–14; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 722, pl. 88, figs. 20,21; STONE & FURNISH, 1959, ibid., v. 33, p. 219, pl. 32, fig. 3; ETHINGTON, 1959, ibid., v. 33, p. 269, pl. 40, fig. 12; SWEET, *et al.*, 1959, ibid., v. 33, p. 1040, pl. 133, fig. 4.

Remarks.—Representatives of this distinctive species are not uncommon in the Mount Hope member of the Fairview, from which 56 individuals have been collected. Fairmount strata, however, have yielded only one specimen. All these forms are closely similar to the types of *Ambalodus triangularis* and are referred to that species without question. The species has been adequately discussed in several recent reports and study of the specimens at hand adds no significant detail to current knowledge of specific characters.

Occurrence.—Mount Hope member, Fairview formation, at localities 14806, 14808, 14809, 14810, 14811, 14812, 14813, 14814. Fairmount member (12 feet below top), locality 14811.

Types.—Figured hypotype, OSU 22820.

Genus AMORPHOGNATHUS Branson & Mehl, 1933

Type species: *Amorphognathus ordovicica* Branson & Mehl, 1933.

AMORPHOGNATHUS ORDOVICICA Branson & Mehl

Pl. 37, figs. 13,15

Amorphognathus ordovicica BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 127, pl. 10, fig. 38; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 63; RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 123, pl. 9, fig. 4; STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 220, pl. 32, fig. 12.
?Amorphognathus ordovicicus RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 283, pl. 20, figs. 47–49.

Remarks.—The original description of this species, and of the genus for which it serves as type, makes no mention of the character of the under surface of the element. However, in elements that are otherwise comparable in every respect, each lobe of the platform is longitudinally excavated or grooved on its under side. Consequently, such a configuration may be taken to be

characteristic of the genus as a whole. It should be noted, though, that the limbs of several species (including the type of *Polyplacognathus* Stauffer) have longitudinally carinate, or keeled, under surfaces, suggesting that they were attached to the supporting tissue by a "tongue and groove" arrangement. Possibly such species do not belong in *Amorphognathus s.s.* and Stauffer's *Polyplacognathus* may be a valid receptacle for them. The specimens at hand are clearly representatives of *Amorphognathus* and seem to be conspecific with *A. ordovicica* Branson & Mehl. For this reason, no direct comparisons were made with definite representatives of *Polyplacognathus ramosa* Stauffer and the problem outlined above cannot be solved satisfactorily from a study of Fairview specimens. If *Amorphognathus* is interpreted strictly, it seems to be confined to rocks of Upper Ordovician age (Eden and early Maysville in North America; zone of *Dicellograptus complanatus* in Wales). If forms like *Polyplacognathus ramosa* are included in *Amorphognathus*, the stratigraphic range is considerable more extended (Porterfield through early Maysville in North America). No representatives of either *Amorphognathus* or *Polyplacognathus* are known from rocks younger than the Fairview in the Cincinnati region, and, in the Fairview, *A. ordovicica* is most common in the lower ten feet of the formation.

Occurrence.—Mount Hope member, Fairview formation, all localities except 14805: Fairmount member, Fairview formation, at locality 14811. Mount Hope collections contain 39 representatives of the species; two specimens have been found in Fairmount strata.

Types.—Figured hypotypes, OSU 22821, 22822.

Genus APHELOGNATHUS Branson, Mehl & Branson, 1951
Type species: *Aphelognathus grandis* Branson, Mehl & Branson, 1951.

Paired, individually asymmetrical, arched, blade-like conodont-elements with posterior limb slightly offset and sometimes twisted out of vertical plane defined by anterior limb. Deeply excavated basally; subapical navel enclosed by a sheath that flares broadly on both the inner and outer sides. Outer sheath flares slightly posterior to axis of cusp; inner sheath flares somewhat anterior to cusp base.

Remarks.—*Aphelognathus* is similar to and probably closely related to Ordovician species of *Ozarkodina*. The genus was considered by its authors to be most closely related to *Dichognathus*. However, in typical representatives of the latter, the processes are formally inner lateral and posterior in position rather than anterior and posterior. *Aphelognathus grandis*, the type species, is a long-ranging (Arnheim-Elkhorn) Richmondian form; *A. acutidentata*, which may be based on juvenile forms of *A. grandis*, has been reported (Branson, Mehl & Branson, 1951) from the Arnheim and Liberty formations of the Richmond group in Kentucky and Indiana. Rhodes (1955) reported a third species of *Aphelognathus*, *A. elegantus*, from the Keisley limestone of Westmorland, England. The Keisley limestone is considered by Rhodes and others to be early Ashgillian and probably of about the same age as the Maysvillian strata from which the types of *A. irregularis*, n. sp., were derived.

APHELOGNATHUS IRREGULARIS
Pulse & Sweet, n. sp.
Pl. 36, figs. 15,17

Diagnosis.—A robust species of *Aphelognathus* with a short, somewhat twisted posterior, and a relatively long, slightly bowed anterior process, which join beneath the cusp at an angle of about 140 degrees. Cusp separated from major anterior denticles by a gap in which there is a series of about four minor denticles that tend to become overgrown by and eventually included in the cusp base.

Description of types.—Cusp stout, reclined, compressed, with blade-like anterior and posterior margins and somewhat inflated sides. Anterior process somewhat less than twice the length of posterior process. It is spatulate, subtriangular in transverse section, and slightly "crimped" longitudi-

nally along its junction with basal sheath. Anterior process surmounted by about 10 stout, slightly compressed denticles, the anterior six of which are subequal in size and separated from the cusp by four laterally confluent denticles of much smaller size. These are overgrown by and included in the anterior blade-like edge of the cusp. Posterior process like anterior process in transverse section, but shorter and surmounted by at least six laterally compressed, distally discrete denticles that increase regularly in height from the extremity of the process toward the cusp. The anterior denticles of this series, like the posterior few of the anterior series, tend to be overgrown by the laminae of the posterior, blade-like margin of the cusp. Posterior process bowed slightly in direction opposite to that of anterior process, and slightly twisted out of plane that includes cusp and anterior process.

Base deeply excavated; excavation walled by thin, laterally flaring sheath. Sheath flares widely beneath cusp on both inner and outer sides of unit. Outer flare slightly farther toward posterior than inner flare, so that, in superior view, the base of the posterior process appears to be slightly offset.

Remarks.—The most distinctive feature of *Aphelognathus irregularis*, n. sp., is the configuration of the anterior denticle series. The distinct tendency for the four or five anteriormost denticles to be small and to become overgrown by the anterior margin of the cusp distinguishes *A. irregularis* from *A. grandis*, the type species of *Aphelognathus*. It should also be noted that the limb denticles of *A. irregularis* tend to be compressed, whereas those of *A. grandis* are shown (Branson, Mehl & Branson, 1951) to be peg-like and little compressed laterally.

Occurrence.—Of the nearly 7000 identifiable conodont-elements collected from the Fairview, only 15 are referable to this species. All these specimens are from the Fairmount member, at localities 14806, 14808, 14809, 14810, 14811, 14812, 14814. Eleven of the 3000 specimens in the McMillan collections at hand belong in *Aphelognathus irregularis*.

Types—Cotypes, OSU 22848, 22849.

Genus BELODINA Ethington, 1959
Type species: *Belodus grandis* Stauffer, 1935.

BELODINA INCLINATA (Branson & Mehl)?
Pl. 37, figs. 10,11

?Belodus inclinatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 125–126, pl. 10, fig. 24.

Fairview specimens referred tentatively to this species are all alike in that the cusp is very broadly curved, being virtually straight posteriorly and somewhat proclined anteriorly. The entire element is laterally compressed and its sides bear fine longitudinal striations that are essentially parallel to the inferior cusp margin. The outer side is broadly convex transversely; the inner side is marked by two parallel longitudinal constrictions, one near the base of the denticle series, the other close to the inferior margin of the cusp. A rounded lateral ridge parallels the inferior margin. The denticle series contains five to six small, sharp, laterally compressed denticles, of which the anterior two or three are inclined forward. The posterior end of the denticle series is produced into a compressed flange-like "heel." The basal excavation consists of two conical elements that are confluent proximally, but discrete distally. The upper of these is an obtusely subconical cavity, restricted for the most part to that portion of the element beneath the "heel." Its apex is located beneath the angle formed by the infero-anterior corner of the "heel" and the posterior margin of the denticle series. The lower of the two cavities is subconical in shape and tapers anteriorly to a thread-like tube, the tip of which is at approximately mid-length of the element. The posterior margin of the entire element is somewhat incurved, or "crimped."

Remarks.—Four Fairview specimens seem to be closely similar to Branson & Mehl's *Belodina inclinata*. However, it has not been possible to make direct comparison with the type of *B. inclinata* and the Fairview specimens differ somewhat from the only illustration and description available. The configuration of the base and the number of denticles are somewhat different, as is the size of the element. Furthermore, the ridge along the anterior margin apparently has a

sharper crest in the illustrated type than in the Fairview specimens. It is difficult to determine from the few representatives of this species known what degree of morphological variation may be permissible. For this reason, the specimens at hand are only tentatively referred to *Belodina inclinata*. Further study may serve to indicate that they are, indeed, conspecific—or they may represent a previously undescribed species.

Occurrence.—This species is rare in the Fairview formation. Only four specimens were collected from the lower 15 feet of the Mount Hope member at localities 14808 and 14802. No representatives of this species or of the genus to which it belongs are known from any younger rocks in the Cincinnati region.

Types.—Figured hypotypes, OSU 22823, 22824.

Genus CORDYLODUS Pander, 1856

Type species: *Cordylodus angulatus* Pander, 1856.

CORDYLODUS DELICATUS Branson & Mehl
Pl. 36, figs. 4,7

Cordylodus? delicatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 129, pl. 10, figs. 14,15; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 82; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 732, pl. 88, fig. 5.

Cordylodus delicatus SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1044, pl. 132, figs. 12, 14,17.

Subcordylodus delicatus BRANSON, 1944, Missouri Univ. Studies, v. 19, p. 89,90, pl. 13, figs. 14,15; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 194; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 288, pl. 41, fig. 13.

Cordylodus rectilineatus RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 300,301, pl. 22, figs. 172–175.

Cordylodus elongatus RHODES, 1953, ibid., p. 299, pl. 21, figs. 114–118.

Remarks.—Fairview and McMillan representatives of this distinctive species are closely similar to the types and to figured specimens from various Middle and Upper Ordovician localities in North America and Europe. In the Cincinnati region, *Cordylodus delicatus* ranges through the Covington group into the lower part (Arnheim) of the superjacent Richmond group.

Occurrence.—At least a few specimens of *Cordylodus delicatus* have been recovered from every unit at every Fairview locality sampled, and, in the McMillan, representatives of this species constitute some 25–27 percent of the total number of conodont-elements collected.

Types.—Figured hypotypes, OSU 22825, 22826.

CORDYLODUS EXCAVATUS Sweet, Turco, Warner, & Wilkie
Pl. 35, figs. 11,15

Cordylodus excavatus SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1045, pl. 132, fig. 16.

Remarks.—This species is represented in the Fairview (to which it is virtually restricted) by a larger number of more nearly complete specimens than were available to Sweet, *et al.* As indicated in the type description, the cusp is massive, erect, subcardioid to subtriangular in cross section, and longitudinally grooved posteriorly for at least the proximal third of its length. The cusp groove extends posteriorly for a short distance and embraces the anteriormost denticle of the posterior series. The posterior process is long and surmounted in complete specimens by at least eleven peg-like denticles that are ovate in cross section, discrete for virtually their entire length, and uniformly inclined toward the posterior. The under surface of the posterior process is excavated for its entire length and the process itself is slightly bowed.

Occurrence.—The types of this species are from the McMicken member of the Eden formation, but the species is not common in Edenian strata. In the Fairview, however, the species is relatively abundant; no representatives of it are known definitely to occur in rocks younger than Fairview in the standard Cincinnatian sequence. Very few units sampled failed to yield at least a few specimens referable to *Cordylodus excavatus*.

Types.—Figured hypotypes, OSU 22827, 22828.

CORDYLODUS FLEXUOSUS (Branson & Mehl)
Pl. 36, figs. 4,7

Prioniodus? flexuosus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 130, pl. 10, fig. 16; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 171.

Cyrtoniodus complicatus STAUFFER, 1935, Geol. Soc. America, Bull., v. 46, p. 140,158, pl. 11, figs. 44,46,48–51; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 85; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 302, pl. 22, figs. 193–196; SWEET, 1955, Jour. Paleontology, v. 29, p. 254, pl. 28, fig. 3; GLENISTER, 1957, ibid., v. 31, p. 732, pl. 88, fig. 16; ETHINGTON, 1959, ibid., p. 274, pl. 40, fig. 7.
Cordylodus flexuosus SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1045, pl. 132, fig. 13.

Remarks.—Fairview and McMillan specimens referred to this species compare closely with the figured type and with representatives of *C. flexuosus* described from the typical Eden. For this reason, they are referred to *C. flexuosus* without question.

Occurrence.—*C. flexuosus* is more ab ndant in the Mount Hope than in the Fairmount, but it is represented by fewer individuals than are either *C. delicatus* or *C. excavatus*. Nevertheless, specimens were collected from most units at all localities sampled. In the McMillan, representatives of this species were found in samples from every unit studied and 9–12 percent of our McMillan conodont-elements are referred to this species.

Types.—Figured hypotypes, OSU 22829, 22830.

Genus DICHOGNATHUS Branson & Mehl, 1933

Type species: *Dichognathus prima* Branson & Mehl, 1933.

DICHOGNATHUS BREVIS Branson & Mehl
Pl. 35, figs. 9,14

Dichognathus brevis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 113, pl. 9, figs. 24–26; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 86; SWEET, 1955, Jour. Paleontology, v. 29, p. 258, pl. 28, fig. 14; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 734, pl. 88, figs. 10,12; SWEET *et al.*, 1959, Jour. Paleontology, v. 33, p. 1047, pl. 132, fig. 7.

Remarks.—Fairview and McMillan representatives of this species are highly variable, but are closely related as a group to one of the *Dichognathus* "form-trends" described as *Dichognathus brevis* by Branson & Mehl. As in Sweet, *et al.*, more importance was assigned to the size of the process angle than to the length of the limbs or relative size of the cusp. In *D. brevis*, the outer process angle is between 35 and 45 degrees, thus distinguishing it from *D. typica*, in which the angle is 20–30 degrees, and *D. extensa*, which has an outer process angle of 10 degrees or less.

Occurrence.—Abundant in every unit of the Mount Hope and Fairmount members, Fairview formation, at all localities sampled. Found throughout McMillan formation but representatives constitute only one percent of the entire McMillan collection.

Types.—Figured hypotypes, OSU 22831, 22832.

DICHOGNATHUS TYPICA Branson & Mehl
Pl. 37, figs. 6,14

Dichognathus typica BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 113,144, pl. 9, figs. 27–29; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 96; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 735, pl. 88, figs. 4,6; ETHINGTON, 1959, ibid., v. 33, p. 274, pl. 40, fig. 17; SWEET, *et al.*, ibid., v. 33, p. 1048, pl. 132, fig. 6.
?Dichognathus cf. *D. typica* RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 317, pl. 22, figs. 178–180; SANNEMANN, 1955, Neues Jahrb. Geol. Paläont., abh., Bd. 102, p. 25, pl. 2, fig. 13.

Remarks.—To this species are assigned all Fairview and McMillan *Dichognathus* with an outer process angle of between 35 and 45 degrees and deeply excavated lateral processes of essentially equal length. Representatives of this species at hand are identical to Eden forms and closely similar to the types figured by Branson & Mehl.

Occurrence.—Less abundant than *Dichognathus brevis*, but common in nearly every unit at all Fairview localities sampled. Rare in the McMillan, but found sporadically throughout the formation.

Types.—Figured hypotypes, OSU 22833, 22834.

Genus DREPANODUS Pander, 1856

Type species: *Drepanodus arcuatus* Pander, 1856.

DREPANODUS HOMOCURVATUS Lindström
Pl. 35, figs. 4,13

Oistodus curvatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 110,111, pl. 9, figs. 4,10,12; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 134; RHODES,

1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 295, pl. 21, figs. 82,89,90, pl. 22, figs. 157–161; SWEET, 1955, Jour. Paleontology, v. 29, p. 251. pl. 28, fig. 7.

Drepanodus homocurvatus LINDTRÖM, 1954, Geol. Fören. Förhandl., bd. 76, p. 563, pl. 2, figs. 23,24,29, text-fig. 4d; SANNEMANN, 1955, Neues Jahrb. Geol. Paläont., abh., Bd. 102, p. 26, pl. 2, fig. 4; pl. 1, fig. 14; LINDSTRÖM, 1957, Geol. Fören. Förhandl., bd. 79, p. 164; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 725, pl. 86, fig. 13; pl. 87, figs. 1–6,8; STONE & FURNISH, 1959, ibid., v. 33, p. 222, pl. 31, fig. 8; ETHINGTON, 1959, ibid., p. 276, pl. 36, fig. 16; SWEET, *et al.*, 1959, ibid., v. 33, p. 1049, pl. 130, fig. 7.

Stone & Furnish (1959) noted some variation in details of curvature, anterior flexure, and development of the anterior and posterior edges in the many upper Bighorn specimens they were studying. Similar variations occur in the numerous representatives of *Drepanodus homocurvatus* at hand, but little significance is attached to them. Clearly, elements like this represent the more conservative parts of the conodont animal, for similar (and almost certainly conspecific) elements are found in Lower, Middle, and Upper Ordovician rocks.

Occurrence.—This form is abundant throughout both the Fairview and McMillan formations. At least a few specimens have been found in all units sampled at every locality.

Types.—Figured hypotypes, OSU 22835, 22836.

DREPANODUS SUBERECTUS (Branson & Mehl)
Pl. 35, figs. 2,7

Oistodus suberectus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 111, pl. 9, fig. 7; FAY; 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 136; RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 295, pl. 21, figs. 93,94; pl. 22, figs. 166,167; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 726, pl. 86, figs. 12,14.

Drepanodus suberectus LINDSTRÖM, 1954, Geol. Fören. Förhandl., bd. 76, p. 568, pl. 2, figs. 21,22; SANNEMANN, 1955, Neues Jahrb. Geol. Paläont., Bd. 102, p. 27, pl. 1, fig. 22; pl. 2, fig. 1; LINDSTRÖM, 1957, Geol. Fören. Förhandl., bd. 79, p. 164; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 276, pl. 39, fig. 17; STONE & FURNISH, 1959, ibid., v. 33, p. 222, pl. 31, fig. 7; SWEET, *et al.*, 1959, ibid., v. 33, p. 1049, pl. 130, fig. 4.

Remarks.—The specimens referred to this species compare favorably with the types and other illustrated representatives of the species. It should perhaps be noted that certain Fairview representatives of *Drepanodus homocurvatus* approach *D. suberectus* in outline. They may be distinguished from *D. suberectus*, however, by the fact that the anterior and posterior margins of the latter are typically blade-like.

Occurrence.—Representatives of *Drepanodus suberectus* constitute about two percent of the total number of conodont-elements collected from the Mount Hope and about one percent of those collected from the Fairmount. The species is not known from the Bellevue or Mount Auburn, but is present in very limited numbers in the Corryville member of the McMillan formation.

Types.—Figured hypotypes, OSU 22837, 22838.

Genus EOLIGONODINA Branson, Mehl & Branson, 1951

Type species: *Eoligonodina robusta* Branson, Mehl & Branson, 1951.

EOLIGONODINA FAIRMOUNTENSIS Pulse & Sweet, n. sp.
Pl. 35, fig. 17

In the Fairview collections at hand, there is a single, well preserved *Eoligonodina* that differs greatly from previously described representatives of the genus and clearly belongs in a new species. The writers are reluctant to base a new species on a single specimen; however, this specimen is virtually complete and so distinctive that it must certainly be typical of the undescribed taxon to which it belongs. This new species is diagnosed as follows:

Robust conodont-elements with massive, regularly recurved cusp and prominently denticulated posterior and inner lateral processes. Cusp subquadrate in transverse section; anterior and outer sides smooth, broadly convex, and not distinctly set off from one another. Proximally, the posterior side of the cusp is marked by a deep, chan-

nel-like, longitudinal groove; distally, this groove loses its distinctness and toward the apex of the cusp the posterior margin was undoubtedly broadly convex, but set off from the outer and inner sides by rather abruptly rounded shoulders. The inner cusp face is broadly convex and separated from the smooth anterior margin by a sharp-crested longitudinal carina. The posterior margin of the cusp is produced into a thick, longitudinally excavated process, the upper surface of which bears a series of discrete, posteriorly inclined denticles that are somewhat compressed laterally. The anteriormost denticle of this series is embraced basally by a posterior extension of the longitudinal cusp groove.

The antero-lateral cusp carina is continuous basally with a thick, denticulated inner lateral process that extends well below the plane of the cusp base and curves gently toward the posterior distally. This process bears on its upper surface a series of five long, stout, subcircular, discrete denticles that are subparallel to the cusp. That is, these denticles appear to be developed in successive planes, each more or less parallel to that defined by the cusp and its posterior process. The under surface of the entire element is excavated. The excavation is deepest under the cusp, and branches of it continue beneath the two processes. These process grooves become progressively shallower distally.

Remarks.—Eoligonodina fairmountensis is most nearly comparable in gross form to *E. robusta*, but differs in that the posterior margin of the cusp is distinctly and deeply grooved (at least proximally) and the denticles of the inner lateral process are long and developed in planes essentially parallel to that defined by the cusp and posterior process. It differs from *E. elongata* (Rhodes), of the Eden and late Caradoc, and *E. richmondensis* Branson, Mehl & Branson, of the Richmond, in being more massive and in having a more highly developed inner lateral process with discrete, recurved denticles.

Occurrence.—Fairmount member, Fairview formation, locality 14810.

Type.—Holotype, OSU 22839.

Genus KEISLOGNATHUS Rhodes, 1955

Type species: *Keislognathus gracilis* Rhodes, 1955.

KEISLOGNATHUS GRACILIS Rhodes

Pl. 36, fig. 3

Keislognathus gracilis RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 131, pl. 7, figs. 7,8; SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1051, pl. 132, fig. 11.

?Keislognathus sp. STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 223, pl. 32, fig. 6.

The specimens at hand compare favorably with the illustrated types of *Keislognathus gracilis* and with those from the Eden of Ohio described by Sweet, *et al. K. simplex* Ethington, the only other species of the genus known, differs from *K. gracilis* and the specimens at hand in that it possesses a prominent denticle on either side of the cusp and neither of its lateral processes is denticulate.

Occurrence.—Keislognathus gracilis is rare in the Fairview. The seven specimens at hand were collected from the lower 15 feet of the Mount Hope member at localities 14808 and 14814.

Types.—Figured hypotype, OSU 22840.

Genus OISTODUS Pander, 1856

Type species: *Oistodus lanceolatus* Pander, 1856.

OISTODUS ABUNDANS Branson & Mehl

Pl. 35, figs. 1,8

Oistodus abundans BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 109, pl. 9, figs. 11,17; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 134; SANNEMANN, 1957, Neues Jahrb. Geol. Paläont., Bd. 102, p. 4,28, pl. 2, fig. 8; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 725, pl. 86, fig. 5; ETHINGTON, 1959, ibid., v. 33, p. 282, pl. 39, fig. 21; SWEET, *et al.*, 1959, ibid., v. 33, p. 1052, pl. 130, fig. 3.

The basal outline of the Fairview and McMillan specimens referred to this species exhibits some variation. That is, the flange-like blade along the upper margin of the basal sheath is prominent in some forms and only weakly developed in others. In other respects, however, the specimens at hand are closely similar to the types and almost exactly like the representatives of *O. abundans* described by Sweet, *et al.*, from the subjacent Eden formation.

Occurrence.—Specimens referable to this abundant and long-ranging species constitute seven percent of the writers' Fairview collections and were found in almost every sample collected, regardless of locality. Seven percent of our Bellevue conodont-elements belong in *Oistodus abundans*, but two percent of those from the Corryville and Mount Auburn members of the McMillan formation are referable to this species.

Types.—Figured hypotypes, OSU 22841, 22842.

OISTODUS INCLINATUS Branson & Mehl
Pl. 35, figs. 10,12

Oistodus inclinatus BRANSON & MEHL, 1933' Missouri Univ. Studies, v. 8, p. 110, pl. 9, fig. 8; BRANSON, MEHL & BRANSON, 1951, Jour. Paleontology, v. 25, p. 3, pl. 2, figs. 5,6; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 135; GLENISTER, 1957, Jour. PALEONTOLOGY, v. 31, p. 726, pl. 86, fig. 11; STONE & FURNISH, 1959, ibid., v. 33, p. 224, pl. 31, fig. 6; SWEET, *et al.*, 1959, ibid., v. 33, p. 1053, pl. 131, fig. 6.

The specimens at hand compare almost exactly with the types of this distinctive species; hence there can be little doubt but that they are conspecific.

Occurrence.—Even though *Oistodus inclinatus* is not as common in the Fairview as *O. abundans*, a few representatives of the species have been found in nearly every sampled horizon of the Fairview formation. The species is not well represented in the McMillan, but ranges through the formation and accounts for about one percent of the total of our McMillan conodont collection.

Types.—Figured hypotypes, OSU 22843, 22844.

Genus OULODUS Branson & Mehl, 1933
Type species: *Oulodus mediocris* Branson & Mehl, 1933.

OULODUS CASTERI Pulse & Sweet, n. sp.
Pl. 36, figs. 1,8,12

Oulodus mediocris? SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1054, pl. 133, fig. 5.

Late Eden, Fairview, and McMillan strata have yielded many distinctive conodont-elements that undoubtedly belong in *Oulodus* Branson & Mehl, but appear to represent an undescribed species of that genus. Consequently, these specimens are herein referred to *Oulodus casteri*, n. sp., named in honor of Professor Kenneth E. Caster, of the University of Cincinnati. *Oulodus casteri* is diagnosed as follows:

A robust species of *Oulodus* with a prominent cusp, and lateral processes of subequal length and size that are confined for the most part to a plane that may be conceived to bisect the cusp longitudinally.

Description of types.—Cusp long, stout, regularly recurved, subcircular to somewhat laterally compossed in section, and more or less distinctly costate laterally. Lateral costae continuous basally with conspicuous, denticulated, compressed lateral processes that are essentially confined to the same plane proximally, but twisted out of this plane distally. One process tends to be twisted downward and anteriorly, whereas the other curves inward and posteriorly in its distal third. Process denticles long, discrete, somewhat compressed or subcircular in section, and either erect or somewhat recurved posteriorly. Under surface of unit deeply excavated beneath cusp and lateral processes. Basal sheath rather prominently flared toward the posterior at the base of cusp.

Remarks.—This new species differs from *Oulodus mediocris* Branson & Mehl, the type species of *Oulodus*, in that the lateral processes are of about the same length and are confined for the most part to a common plane. In *O. mediocris*, apparently, the two processes are of unequal length and lie in planes essentially normal to one another. In general appearance, *O. casteri* is strikingly similar to *O. primus* (Stauffer), the types of which, however, are not only considerably older than the specimens at hand, but also have lateral limbs of greatly different length and a cusp that is much less prominent than that of *O. casteri*.

Occurrence.—Rare in Southgate and McMicken member of the Eden; abundant throughout the Fairview formation at all localities sampled, and represented by one fragmentary specimen in the Corryville

member of the McMillan at locality 14815.

Types.—Syntypes, OSU 22845, 22846, 22847.

Genus OZARKODINA Branson & Mehl, 1933
Type species: *Ozarkodina typica* Branson & Mehl, 1933.

OZARKODINA ROBUSTA Stauffer
Pl. 35, figs, 18,19

Ozarkodina robusta STAUFFER, 1935, Jour. Paleontology, v. 9, p. 612, pl. 71, figs. 1,3,6,7,9–13,15,21; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 138; SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1055, pl. 133, fig. 14.

Remarks.—About a dozen Ordovician species have been referred to *Ozarkodina*, which is based on Middle Silurian types. All the Ordovician species are greatly similar and it is difficult to differentiate them objectively, although this might be done through a statistical study of large collections. It is suspected that such a restudy of the several Ordovician species of *Ozarkodina* would show that some are based on juvenile stages of others, hence, are not distinct species in themselves, for there is a great difference, not only in size, but also in number and arrangement of denticles at various stages of growth in *Ozarkodina*.

In only one described species, *Ozarkodina robusta* Stauffer, are the anterior and posterior processes said to be twisted; hence it is to this species that all our Fairview and McMillan forms are referred. These specimens exhibit the same variations in size, discreteness, sharpness, and number of denticles as do those described from the Eden of Ohio by Sweet, *et al.* (1959).

Occurrence.—About 10 percent of the total number of specimens collected from the Fairview formation and the Bellevue and lower Corryville members of the McMillan formation are herein referred to this species. Nearly 20 percent of the specimens in collections from the upper Corryville and Mount Auburn members of the McMillan belong in this species. Well preserved specimens were found at nearly every horizon at every locality sampled.

Types.—Figured hypotypes, OSU 22850, 22875.

Genus PANDERODUS Ethington, 1959
Type species: *Paltodus unicostatus* Branson & Mehl, 1933.

PANDERODUS GRACILIS (Branson & Mehl)
Pl. 35, figs. 3,6

Paltodus gracilis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 108, pl. 8, figs. 20, 21; BRANSON, MEHL & BRANSON, 1951, Jour. Paleontology, v. 25, p. 6, pl. 1, figs. 1–8; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 144; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 728, pl. 85, figs. 2–5.
Panderodus gracilis ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 285, pl. 39, fig. 1; STONE & FURNISH, 1959, ibid., v. 33, p. 225, pl. 31, fig. 2; SWEET, *et al.*, 1959, ibid., v. 33, p. 1056, pl. 131, fig. 1.

The Fairview and McMillan specimens referred to *Panderodus gracilis* compare favorably with the illustrated types. Minor individual variations in size, degree of curvature, and of cusp cross section were noted, but as a group these forms are so similar to each other and to the types that they are referred to *P. gracilis* without question.

Occurrence.—*Panderodus gracilis* constitutes only one percent of the total of our Fairview collections, and we have only one specimen from the mid-portion of the McMillan formation at Locality 14815. All the specimens now known from the Fairview are from the Mount Hope member. Furthermore, most of the forms at hand come from the lower or middle part of the member.

Types.—Figured hypotype, OSU 22853, 22854.

PANDERODUS ROBUSTUS (Branson, Mehl & Branson)
Pl. 35, fig. 5

Paltodus robustus BRANSON, MEHL & BRANSON, 1951, Jour. Paleontology, v. 25, p. 8, pl. 1, figs. 28–33.

A single specimen from the upper part of the Mount Hope member of the Fairview is referred to this species. This specimen is not precisely like the figured syntypes of *Paltodus robustus* Branson, Mehl & Branson, but it is closely similar in that it is rather abruptly reclined at mid-length, deeply excavated basally, and has a series of longitudinal costae disposed in a fashion very much like the types of *P. robustus*. As a consequence, the mid-length cross sections

of the specimen at hand and *P. robustus* are virtually the same. It should be noted that the Fairview specimen is somewhat less robust than any of the four syntypes and the base does not flare quite so prominently posteriorly. The syntypes, however, exhibit some variation in this respect, also, so it is difficult to attach any particular significance to the fact that the Fairview specimen is narrower basally than the types.

Occurrence.—The syntypes of *Panderodus robustus* are from the Whitewater formation of the typical Richmond. The species is also known (Branson, Mehl & Branson, 1951) from the Elkhorn formation. The only representative of this species known from the Fairview formation came from the upper part of the Mount Hope member at locality 14806.

Types.—Figured hypotype, OSU 22852.

Genus PHRAGMODUS Branson & Mehl, 1933
Type species: *Phragmodus primus* Branson & Mehl, 1933.

PHRAGMODUS UNDATUS Branson & Mehl
Pl. 37, figs. 4,16,18,19; Text-fig. 2A-E

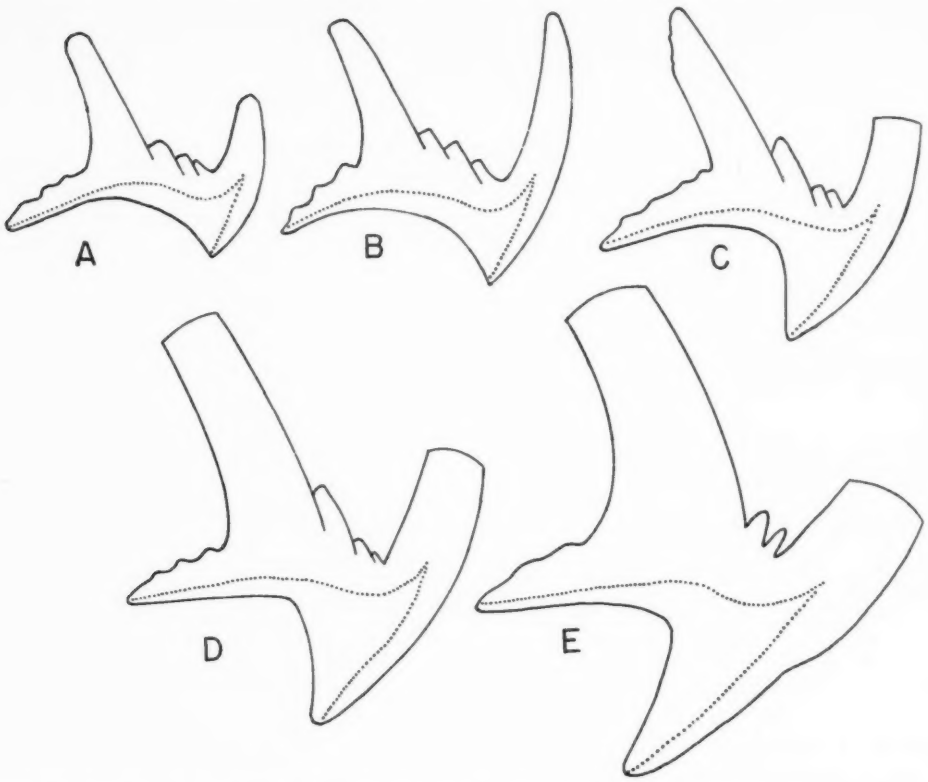
Phragmodus undatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 115,116, pl. 8, figs. 22–26; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 146; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 733, pl. 88, figs. 1,2; ETHINGTON, 1959, ibid., v. 33, p. 285, pl. 41, fig. 12; SWEET, *et al.*, 1959, ibid., v. 33, p. 1058, pl. 133, figs. 7,10,13.

Remarks.—As previous writers (Branson & Mehl, 1933; Glenister, 1957; Ethington, 1959; Sweet, *et al.*, 1959) have pointed out, *Phragmodus undatus* is a rather variable species. Its principal distinguishing characteristic seems to be the possession of a sinuous posterior process and, as all the *Phragmodus* at hand exhibit such a process, they are herein referred to *P. undatus.*

On the basis of cusp ornamentation, the specimens we are studying can be subdivided into the same three categories outlined by Sweet, *et al.* (1959). That is, the cusp of one group is marked by a posterior and anterior costa; that of a second group has in addition to the posterior and anterior costae, a more or less distinct outer lateral costa. A third group possesses a cusp marked by posterior, incurved anterior, outer lateral, and inner lateral costae. In addition to these groups, some 57 Fairview specimens of *Phragmodus undatus* are robust, massive individuals, exhibiting cusp costation like that of either the first or the second groups just described. At first, these specimens seemed so strikingly unlike other *Phragmodus* that they were thought to represent an undescribed species. However, careful comparison of these specimens with more "typical" *P. undatus* suggests that they are only the robust end-members of a gradational series now thought to include individuals at various stages of growth. The presumed stages represented are shown diagrammatically in Text-figure 2, which was drawn to scale from different Fairview specimens of *Phragmodus undatus.*

Interestingly enough, robust *Phragmodus undatus* (like those herein illustrated in figs. 18, 19, on Plate 37) were not found in large collections from the Eden formation of the Cincinnati region, nor are forms like this known to occur in the McMillan. This could perhaps be taken to mean that these robust *Phragmodus* represent a new species. However, several genera of Fairview conodonts seem to have developed particularly massive elements (some of which do, indeed, represent new species) and this is, at least locally, one of the characteristic things about the Fairview fauna. For this reason, the writers are inclined to attach less significance to the obesity of these Fairview *Phragmodus* than to the fact that they are otherwise so very similar in gross form to the more "typical" *P. undatus.* It is very possible that the appearance of massive and robust elements in several different lines during Fairview time was a function of the environment.

Occurrence.—Eighteen percent of the total number number of conodont-elements collected from the Fairview formation, twenty percent of those from the Bellevue, and less than ten percent of the elements from the Corryville and Mount Auburn members of the McMillan belong in *Phragmodus undatus.* Representatives of the species were found at every horizon in every section sampled. It should be noted that approximately thirty percent of the total number



TEXT-FIG. 2—Outline drawings of *Phragmodus undatus* Branson & Mehl at various stages of growth. Based upon five specimens from the Fairview formation. Approximately ×60.

of Eden conodont-elements studied by Sweet, *et al.*, (1959) were referable to *P. undatus*, so locally, at least, the vertical reduction in importance of the species is of some stratigraphic utility.

Types.—Figured hypotypes, OSU 22855, 22856, 22857, 22858.

Genus PRIONIODINA Ulrich & Bassler, 1926
Type species: *Prioniodina subcurvata* Ulrich & Bassler, 1926.

PRIONIODINA DELECTA (Stauffer)
Pl. 36, figs. 10,11

Ozarkodina delecta STAUFFER, 1935, Geol. Soc. America, Bull., v. 46, p. 148,159, pl. 10, fig. 40; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 137; GLENISTER, 1957, Jour. Paleontology, v. 31, p. 735, pl. 88, figs. 8,9; ETHINGTON, 1959, ibid., v. 33, p. 283, pl. 41, fig. 17.

Ozarkodina? delecta STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 225, pl. 32, figs. 1,2.

Prioniodina delecta SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1060, pl. 131, fig. 11.

?Ozarkodina macrodentata ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 284, pl. 41, fig. 14.

Bowed, blade-like conodont-elements with compressed, erect, or distally reclined cusp that is essentially flat on its outer side, abruptly convex on its inner side, and prominently carinate both anteriorly and posteriorly. Anterior carina continuous with downwardly deflected, compressed anterior process bearing at least four compressed discrete reclined denticles. Posterior cusp

carina continuous with bowed posterior process like anterior process and with six or seven discrete, compressed, sharp-pointed denticles on its upper surface. Under surface of entire element excavated; excavation a deep subconical cavity beneath cusp on inner side of element only.

Remarks.—Fairview and McMillan specimens referred herein to *Prioniodina delecta* (Stauffer) have a somewhat larger and more prominently carinate cusp than the illustrated type. They are like it in other respects, however, and compare favorably with presumably conspecific conodont-elements from the Galena and Maquoketa of Iowa, Eden of Ohio, and upper Bighorn of Wyoming.

Occurrence.—Some three percent of the conodont-elements recovered from the Fairview and 11–13 percent of those found in the McMillan are referable to this distinctive species.

Types.—Figured hypotypes, OSU 22859, 22860.

PRIONIODINA ROTUNDA Sweet, Turco, Warner, & Wilkie
Pl. 36, figs. 14,16,18

Prioniodina rotunda SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1061, pl. 133, fig. 8.

Prioniodina rotunda was erected by Sweet, *et al.*, for a few fragmentary individuals from the uppermost Eden. The species is represented by an abundance of specimens in the Fairview, however, and the writers have prepared the following specific description from a study of elements that are more nearly complete than the types.

The Fairview specimens to which reference is made are all alike in that they are robust, individually asymmetrical, arched, blade-like conodont-elements with thick, massive lateral processes that join at an angle of 100 degrees beneath the cusp. Cusp subquadrate in transverse section basally, with smooth very slightly convex outer side, sharp anterior and posterior carinae, and inner side subdivided into three longitudinal elements by abruptly rounded postero-lateral and less distinct antero-lateral shoulders. Distally, the antero-lateral shoulder disappears and the postero-lateral shoulder becomes less distinct so that at cusp mid-length the cross section is asymmetrically subtriangular, the inner side being subdivided into two elements by a continuation of the indistinct postero-lateral shoulder. Presumably, this shoulder, too, disappears apically. Anterior process thick, slightly bowed, bearing three or four, stout, widely spaced, peg-like denticles that are subcircular in cross section Posterior limb bears four or five stout denticles that are like those of the anterior process but smaller in diameter. Under surface of elements deeply excavated beneath cusp; excavation continued as shallow tapering groove to termini of processes. On inner side, sheath of basal excavation flares inward and posteriorly beneath cusp and is embraced between basal continuation of inner lateral cusp shoulders. On the outer side, sheath is smooth and in virtually same plane as processes.

Occurrence.—This robust form is abundant in both the Mount Hope and Fairmount members of the Fairview formation. About seven percent of the total number of conodont-elements collected from the Fairview belong in this species. At least one specimen was recovered from nearly every unit at every locality sampled. The species was not found in McMillan strata.

Types.—Figured hypotypes, OSU 22861. 22862, 22877.

PRIONIODINA VELICUSPIS Pulse & Sweet, n. sp.
Pl. 36, figs. 5,13

Diagnosis.—A robust, arched, bowed *Prioniodina* with large, distally compressed, recurved cusp and processes of unequal length that bear discrete, subcircular denticles. Posterior margin of cusp produced distally into conspicuous "sail-" or "flag-like" flange.

Description of types.—Unit arched and slightly bowed; denticulate margin of posterior process twisted outward. Cusp long, recurved posteriorly, subtriangular in transverse section proximally, with smooth, convex outer side, sharp anterior and posterior costae, and inner side subdivided into two longitudinal elements by abruptly

rounded postero-lateral shoulder. Distally, the shoulder disappears so that at cusp mid-length the cross section is lenticular. The posterior cusp margin is produced abruptly backward at mid-length to form a flaring, flange-like process, the posterior margin of which is broadly convex. The cusp and its posterior flange taper regularly toward the apex.

Posterior process thick, slightly bowed; upper side bears six, stout, discrete, subcircular, posteriorly inclined denticles. Anterior process short and more or less in plane of cusp; upper side with one or two short, stout, anteriorly inclined denticles. Excavation wide, deep, and subconical beneath cusp, becoming shallow and narrower in width toward termini of processes. On inner side, sheath of basal excavation flares broadly inward and posteriorly beneath cusp; on outer side sheath is somewhat inflated beneath cusp, but is turned inward throughout length of element. Sheath smooth and continuous with basal portion of processes and cusp.

Remarks.—The massive form of *Prioniodina velicuspis* together with its conspicuously "flag-shaped" cusp and inwardly twisted base, serve to distinguish it from previously described species.

Occurrence.—Representatives of *Prioniodina velicuspis* constitute two percent of the total number of conodont-elements collected from the Fairview formation. The species is well represented in the Mount Hope member, but appears to be relatively more abundant in the Fairmount member. At least a few specimens were found in samples from every Fairview section studied, but none have yet been recovered from typical McMillan strata.

Types.—Figured cotypes, OSU 22863, 22864.

Genus TETRAPRIONIODUS Lindström, 1954
Type species: *Tetraprioniodus robustus* Lindström, 1954.

TETRAPRIONIODUS SUPERBUS (Rhodes)
Pl. 36, fig. 2

Rosagnathus superbus RHODES, 1955, Geol. Soc. London, Quart. Jour., v. 111, p. 129, pl. 7, figs. 1–4.

A single specimen from the basal Mount Hope in the Bald Knob section (14808) at Cincinnati is clearly a *Tetraprioniodus* and, even though fragmentary, it appears to be a representative of *T. superbus* (Rhodes), known heretofore only from the Keisley limestone of Westmorland, England. Ethington (1959) referred strikingly similar forms from the Dubuque formation of Iowa to *Tetraprioniodus parvus* Ethington, distinguished from *T. superbus* by a longer inner anterior process and fewer denticles on the lateral processes. In other respects, both *T. superbus* and *T. parvus* are alike, and if dentiticulation is as variable a feature in *Tetraprioniodus* as it is in other conodont genera, it is debatable how much significance should be attached to such minor variations.

Occurrence.—Basal Mount Hope member, Fairview formation, locality 14808.

Types.—Figured hypotype, 22876.

Genus TRICHONODELLA Branson & Mehl, 1948
Type species: *Trichognathus prima* Branson & Mehl, 1933.

TRICHONODELLA ANGULATA Sweet, Turco, Warner, & Wilkie
Pl. 37, figs. 2,7

Trichonodella angulata SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1064, pl. 131, figs. 9,13.

Fairview and McMillan conodont-elements referred to this species are strikingly similar to the types described from the Eden formation of Ohio and Kentucky by Sweet, *et al.*, in 1959. The species was adequately discussed by its authors and the writers can add nothing in the way of detail to their description.

Occurrence.—*Trichonodella angulata* is abundant in the Mount Hope and lower Fairmount, but relatively less abundant in the upper Fairmount at every locality sampled. Some four percent of the total number of conodont-elements in the Fairview collections at hand belong in this species. The species is also well represented in the McMillan formation, and 5–10 percent of the elements collected from most McMillan samples are referable to it.

Types.—Figured hypotypes, OSU 22865, 22866.

TRICHONODELLA SUBUNDULATA Sweet, Turco, Warner, & Wilkie
Pl. 37, figs. 17,20

Trichonodella subundulata SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1065, pl. 131, figs. 2,5,10.

Representatives of this species in collections at hand compare closely with the types, hence there is little doubt as to their specific identity. This species is characterized by a relatively deep, longitudinal groove along the posterior margin of the massive cusp, and process denticles that are antero-posteriorly compressed. Furthermore, the posterior expansion of the base is not denticulate.

Occurrence.—*Trichonodella subundulata* is not uncommon in the Fairview but is less well represented than other species of the genus in both the Mount Hope and Fairmount members. Well preserved specimens referred to this species were found at all localities sampled and some 1.2 percent of the total number of Fairview conodonts at hand are included in *T. subundulata*. The species is somewhat more abundantly represented in the McMillan than in the Fairview. About five percent of the elements from every McMillan sample belong in this species.

Types.—Figured hypotypes, OSU 22867, 22868.

TRICHONODELLA TENUIS (Branson & Mehl)
Pl. 37, figs. 3,8

Trichognathus tenuis BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 131, pl. 10, fig. 18; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 199.
Trichonodella tenuis SWEET *et al.*, 1959, Jour. Paleontology, v. 33, p. 1065, pl. 132, figs. 10,15.

Fairview and McMillan conodont-elements referable to this distinctive species compare favorably with those from the Orchard Creek (Maquoketa) shale of Missouri upon which Branson & Mehl based their concept of *Trichonodella tenuis;* hence there is little doubt as to their identity. Closely similar and undoubtedly conspecific forms are also known from the Eden of Ohio and Kentucky and the Maravillas formation of the Marathon Basin, in Texas.

Occurrence.—Representatives of *Trichonodella tenuis* constitute about two percent of the total number of Fairview and McMillan conodont-elements collected by the writers.

Types.—Figured hypotypes, OSU 22869, 22870.

Genus ZYGOGNATHUS Branson, Mehl, & Branson, 1951
Type species: *Zygognathus pyramidalis* Branson, Mehl, & Branson, 1951.
ZYGOGNATHUS DEFORMIS (Stauffer)
Pl. 37, figs. 1,5

Trichognathus deformis STAUFFER, 1935, Geol. Soc. America Bull., v. 46, p. 155–156, pl. 12, fig. 23; FAY, 1952, Univ. Kansas Paleont. Contr., Vertebrata, art. 3, p. 198; SWEET, 1955, Jour. Paleontology, v. 29, p. 257, pl. 29, fig. 6.
Gyrognathus elongata RHODES, 1953, Royal Soc. London, Philos. Trans., ser. B, no. 647, v. 237, p. 318–319, pl. 22, figs. 201,202,205,206; STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 223, pl. 32, fig. 9; ETHINGTON, 1959, ibid., v. 33, p. 279, pl. 40, fig. 13.
Zygognathus deformis SWEET, *et al.*, 1959, Jour. Paleontology, v. 33, p. 1066, pl. 132, figs. 1,5.

As the synonymy above indicates, *Zygognathus deformis* is a distinctive form-species, referred to both *Trichonodella* and *Gyrognathus* by previous authors, but included in *Zygognathus* by Sweet, *et al.*, in 1959. The types are from the Glenwood shale of Minnesota and representatives of the species have been reported from the Decorah shale of Iowa and Minnesota, the Harding formation of Colorado, the Galena formation of Iowa, the Eden formation of Ohio and the Llandeilo limestone of Wales.

Occurrence.—Common in the Mount Hope and lower Fairmount; slightly less well represented in the upper Fairmount member. Abundant throughout the McMillan. About three percent of the total number of conodont-elements collected from the Fairview formation are referable to *Zygognathus deformis*, whereas 6–10 percent of those from the McMillan belong in this distinctive species. Representatives of *Z. deformis* were found throughout the section at every locality sampled.

Types.—Figured hypotypes, OSU 22871, 22872.

ZYGOGNATHUS MAYSVILLENSIS Pulse & Sweet, n. sp.
Pl. 37, figs. 9,12

Diagnosis.—A robust *Zygognathus* with a prominent, slightly recurved cusp that is subtriangular to subquadrate in transverse section. Massive, discretely denticulated inner and outer lateral processes; outer process long and curves outward and then posteriorly into a plane subparallel with the antero-posterior plane of cusp. Inner process shorter than outer process and directed outward, downward, and posteriorly.

Description of types.—Cusp stout, erect to slightly recurved, subquadrate in transverse section basally with two more or less prominent, longitudinal antero-lateral costae, a postero-lateral costa on the outer side, and a broadly rounded postero-lateral shoulder on the innerside. Distally, the antero-lateral costa on the outer side and the postero-lateral shoulder disappear and the cusp cross section becomes lenticular. Outer antero-lateral costa continues downward and outward, and then curves posteriorly as a long, bowed, discretely denticulated process, subparallel to an anterior-posterior plane through the cusp. Inner antero-lateral process similar to outer lateral process, but shorter, directed downward at an angle of about 45 degrees, and defining a curving surface that diverges from an anterior-posterior plane through cusp at about 65 degrees. Upper surfaces of lateral processes set with stout, discrete, subcircular to slightly compressed denticles that are directed outward near cusp but progressively upward toward termini of processes. Basal anterior margin of cusp smooth, curved posteriorly, and continuous with processes. Posterior portion of cusp flares upward into a prominent sheath enclosing a deep, subconical basal cavity, extensions of which occur as broad shallow troughs beneath the lateral processes. Beneath the posterior half of the outer lateral process, the excavation is inconspicous, the under side of the process being broad and virtually flat

Remarks.—The most distinctive features of *Zygognathus maysvillensis* are its obesity, its highly and asymmetrically bowed lateral processes, and its large, recurved, subquadrate to subtriangular cusp. The distinct tendency for the outer lateral process to be directed outward and not quite as markedly downward as that of *Z. pyramidalis* Branson, Mehl & Branson distinguishes *Z. maysvillensis* from the Richmond species. Also, the Fairview species tends to develop denticles that curve progressively upward toward the termini of the processes, whereas the Richmond species exhibits the opposite tendency. The longitudinal cusp carinae of *Zygognathus plebia* and *Z. pyramidalis* are somewhat better developed than those of *Z. maysvillensis*, and appear to be more nearly lateral than antero-lateral in position. It should also be noted that the outer lateral process of *Z. maysvillensis* is longer than the inner process, whereas in *Z. plebia* and *Z. pyramidalis*, the inner lateral process seems invariably to be the longer of the two.

Occurrence.—Representatives of this distinctive species constitute three percent of the total Fairview collection and at least a few specimens were found at almost every Fairview horizon at every locality sampled. Only a few specimens, representing less than one percent of our McMillan collections, were recovered from McMillan strata.

Types.—Cotypes, OSU 22873, 22874.

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(*Explanation of* PLATE 37 *on next page*)

EXPLANATION OF PLATE 37

Figures drawn from photographs of specimens from the Fairview formation.
All ×50.

FIG. *1,5—Zygognathus deformis* (Stauffer). Outer and inner lateral views. Mount Hope member, locality 14808. OSU 22871, 22872.

2,7—Trichonodella angulata Sweet, Turco, Warner & Wilkie. Anterior and posterior views. Mount Hope member, locality 14808. OSU 22865, 22866.

3,8—Trichonodella tenuis (Branson & Mehl). Anterior and posterior views. Mount Hope member, locality 14808. OSU 22869, 22870.

4,16—Phragmodus undatus Branson & Mehl. Inner and outer lateral views. Mount Hope member, locality 14808. OSU 22855, 22856.

6,14—Dichognathus typica Branson & Mehl. Inner and outer lateral views. Mount Hope member, locality 14808. OSU 22833, 22834.

9,12—Zygognathus maysvillensis Pulse & Sweet, n. sp. Anterior and superior views. Mount Hope member, locality 14808. OSU 22873, 22874.

10,11—Belodina inclinata (Branson & Mehl)? Inner and outer lateral views. Mount Hope member, locality 14806. OSU 22823, 22824.

13,15—Amorphognathus ordovicica Branson & Mehl. Superior and inferior views. Mount Hope member, locality 14814. OSU 22821, 22822.

17,20—Trichonodella subundulata Sweet, Turco, Warner & Wilkie. Posterior and anterior views. Mount Hope member, locality 14808. OSU 22867, 22868.

18,19—Phragmodus undatus Branson & Mehl. Outer and inner lateral views showing robust growth stage. Fairmount member, locality 14812. OSU 22857, 22858.

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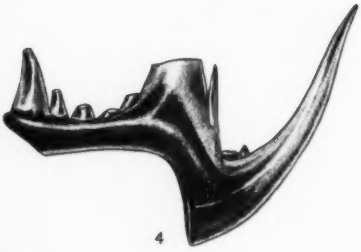
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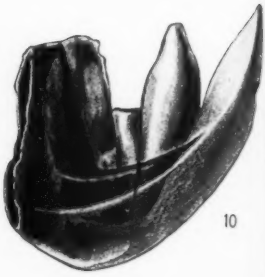
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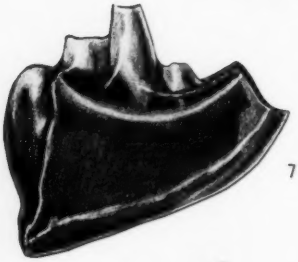
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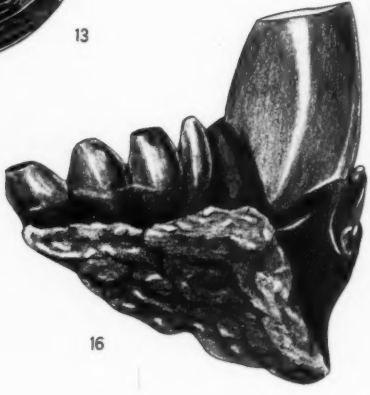
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JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 265–274, PL. 38, MARCH, 1960

UPPER ORDOVICIAN CONODONTS FROM SOUTHERN MANITOBA

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ABSTRACT—Conodonts have been secured in moderate abundance from the Stony Mountain Formation at the type locality. Age of these strata has been previously established as Upper Ordovician on the basis of a varied megafauna. The conodonts are similar to others known from northern Manitoba, western and midwestern United States. Although there are some 30 species identified from the Stony Mountain, only two are described as new. Some are of long-ranging types; others verify correlation of this fauna with the Upper Ordovician of widely separated areas. In particular, representatives of *Belodina*, *Cordylodus*, *Cyrtoniodus*, *Eoligonodina*, *Plegagnathus*, and *Pristognathus* appear significant.

INTRODUCTION

SEARCH for conodonts in the classic Ordovician section of the southern Lake Winnipeg area has provided a representative fauna at one stratigraphic level only. Although abundantly fossiliferous otherwise, the Selkirk Member of the Red River Formation as well as the Penitentiary and Gunton members of the Stony Mountain Formation proved to be virtually barren of microfossils in acetic acid residues. The exception was found in the upper 10 feet of the Gunn Member of the lower Stony Mountain. Samples secured in the vicinity of the type locality produced a moderately abundant conodont fauna. About 80 percent of the specimens represent a single genus, *Panderodus;* somewhat of a characteristic relationship in North American Upper Ordovician faunas. The remainder of the conodonts studied can be classified into 16 additional parataxal genera and about 25 species. Collectively, the fauna is very similar to that known previously from the upper Bighorn Formation in north-central Wyoming.

STRATIGRAPHIC SETTING

Ordovician rocks form a wide outcrop belt along the west side of Lake Winnipeg. The majority of the exposures are relatively inaccessible, and relief is low in most of the area. An interlake plain covers the bed rock except along the lake shore and in isolated erosion remnants that rise above the flat

EXPLANATION OF PLATE 38

All specimens with the exception of Figure 10 are from the Gunn Member of the Stony Mountain Formation in the vicinity of Stony Mountain, Manitoba.

FIG. *1—Plegagnathus nelsoni* Ethington & Furnish, ×70.
2,3—Eoligonodina ulrichi Stone & Furnish, ×110 and ×60. *3,* Illustrates regeneration of the cusp to a more nearly erect position.
4—Phragmodus undatus Branson & Mehl, ×100.
5,6—Trichonodella spp., ×75 and ×85. A mature and juvenile stage of representative specimens.
7—Plectodina dilata Stauffer, ×75.
8,9—Pristognathus bighornensis Stone & Furnish, ×55. Outer and inner views of a nearly complete individual.
10,11—Belodina profunda (Branson & Mehl), ×95 and ×50. *10,* From the Shammattawa equivalent, Knife River Delta on the west side of Hudson Bay for comparison (S.U.I. 10057).
12—Belodina leithi Ethington & Furnish, n. sp., ×55. The holotype.
13—Belodina inclinata (Branson & Mehl), ×85.
14—Prioniodina? sp., ×80.
15—Oulodus? sp., ×70.
16—Cyrtoniodus sinclairi Ethington & Furnish, n. sp., ×60. The holotype.

surface inland. One of the most conspicuous and probably the best known feature is Stony Mountain about 12 miles north of the City of Winnipeg. Baillie (1952) has effectively summarized the Ordovician stratigraphy of this entire area; various other publications contribute to a detailed knowledge of the formations and faunas involved (Whiteaves, 1880 and 1895; Dowling, 1900; Foerste, 1929; Okulitch, 1943; and Stearn, 1956).

Winnipeg.—The base of the sedimentary sequence is the Winnipeg Sandstone of Middle Ordovician age. In the upper shaly portion of the formation, a variety of corals, graptolites, brachiopods, etc., has been reported. The lower more massive sandstone is generally barren, but some of the conodonts known from subsurface are probably from this part of the unit. The authors have examined a few specimens from a well at Hallock, northwesternmost Minnesota, about 80 miles south of Winnipeg. These conodonts are indicative of a Blackriveran age, a fauna best known from the Harding Sandstone of central Colorado (Sweet, 1956). Kupsch (1953, p. 14,17) and Porter & Fuller (1959, p. 142) have suggested that the Winnipeg clastics are chronologically transgressive in a northerly direction, from the central portion of the Williston Basin to the vicinity of Cranberry Portage and Amisk Lake. The fossils identified by Brown (Kupsch, 1953, p. 17) indicate Red River affinities rather than Harding. In the type area, this formation is of the general magnitude of 100 feet in thickness; perhaps two or three times that figure within the Williston Basin (Porter & Fuller, 1959, p. 138; Andrichuk, 1959, p. 2352).

Red River.—A representation of the widespread "Arctic" Ordovician carbonates in southern to west-central Manitoba is called Red River Formation. Foerste (1929) designated two lower units, the Dog Head and Cat Head. These portions were relatively poorly known in comparison to the Selkirk Member at the top, the part which is quarried extensively in the area northeast of Winnipeg. Nomenclature must now be changed, however, for Sinclair (1959) recently presented a revision of the stratigraphy in this region. He regards type Selkirk strata as equivalent to the Dog Head Member and correlates "Upper Mottled Limestone," previously identified as Selkirk in the northern Lake Winnipeg area, with the more shaly Stony Mountain Formation to the south.

Lithology of the entire section is dolomite and dolomitic limestone. Overall thickness varies from only about 250 feet in the southern Lake Winnipeg area to over 500 feet in subsurface. An abundant molluscan and coralline fauna has been generally interpreted to be Upper Ordovician.

Stony Mountain.—Dowling described this formation and named it for exposures on Stony Mountain (1900, p. 88–90). The fauna has been described particularly by Ulrich (1889), Whiteaves (1895), and by Okulitch (1943). The best preservation of fossils is in the lower shale portion of the formation, where an abundance of unaltered free specimens accumulates on weathered exposures. The overall thickness amounts to about 100 feet. Okulitch (1943) divided the section into four members. As now understood, the sequence consists of Gunn Shale at the base, followed by the Penitentiary Dolomite, and the Gunton Dolomite at the top. The most distinctive lithology is that of the Gunn Member which has been recognized over a wide area in subsurface as nodular argillaceous limestone or calcareous shale with common brachiopods, corals, and bryozoans (Ross, 1957, p. 447; Porter & Fuller, 1959, p. 155). Evaporites are recorded in wells, associated with the succeeding carbonates.

Stonewall.—Dolomite above the Stony Mountain has been classified by some authorities as Silurian. Stearn (1956, p. 8–16) has summarized the data and concluded that it is of "latest Ordovician age." Corals, brachiopods, and cephalopods have been found to substantiate this conclusion. The overlying Interlake Group is unquestioned Silurian.

CORRELATIONS

Ever since original studies by Whiteaves and by Ulrich, the main Stony Mountain fauna has been regarded by almost all authorities as Richmondian (Okulitch, 1943, p. 68; Ross, 1957, p. 459). The similarity to the upper Bighorn of north-central Wyoming, upper Maquoketa of Iowa, English

Head and Vauréal of Anticosti, and Shammattawa of the Hudson Bay Lowland is particularly noteworthy. Duncan (1957) has identified the *Catenipora-Palaeophyllum-Calapoecia* fauna of the underlying Red River as pre-Richmondian Upper Ordovician. *Bighornia*, a characteristic Gunn Shale fossil, is widely distributed and has been interpreted by Duncan (1957, p. 611) as representing a stable phylogenetic unit which may provide a basis for subdivision of the Upper Ordovician. However, fossil corals of the Eastern Interior Ordovician are different or lacking. Ross (1957, p. 459) has emphasized the distinctive nature of the brachiopods; *Hesperorthis*, *Dinorthis*, and *Diceromyonia* are characteristic. The large rhynchonellid *Lepidocyclus capax* (Conrad) gens has been reported in beds of probable Richmondian age all through the Rockies, the Midcontinent, type Eastern Interior area, and Hudson Bay. *Sceptropora faculata* Ulrich is a unique bryozoan that was originally described from the Stony Mountain, but it occurs also in the upper Bighorn and upper Maquoketa as well as the Saturday Mountain Formation of Idaho (Ross, 1959, p. 445) and in wells (Andrichuk, 1959, p. 2373). Cephalopods are relatively rare in the Stony Mountain and its direct equivalents; the few forms known are not distinctive in themselves.

Below the Stony Mountain, the Selkirk Member, Red River Formation, contains actinoceratoid cephalopods such as *Armenoceras*, *Selkirkoceras*, and *Huronia* (Foerste, 1929), a fauna which has been generally correlated with early Cincinnatian for over 30 years (e.g., Kirk, 1925). Duncan records (1957, p. 611) the genus *Bighornia* from these same beds, and Nelson (personal communication) has found this fossil to be a fair index for the upper portion of the Ordovician section in the Hudson Bay Lowlands. Doubt concerning exact correlation still exists, however, but Flower (1957, p. 18,22) suggests upper Red River is equivalent to the Eden of the type Eastern Interior.

Above the Stony Mountain, the Stonewall Formation contains a series of Ordovician-type corals, brachiopods, and cephalopods, according to Stearn (1956, p. 15). This same author (p. 16) suggested that the fauna represents an equivalent of uppermost Vauréal or Ellis Bay of the Anticosti section, youngest Ordovician.

CONODONT FAUNA

Occurrence.—Conodonts were secured from two Stony Mountain samples. Both localities represent the type area north of Winnipeg, southern Manitoba.

1. City of Winnipeg Quarry (S.½ sec. 14, Twp. 13, Rge. 2, E. of Princ. Mer.). Location is just north of the village of Stony Mountain. Material taken from a vertical face, near the crusher.
2. Roadside exposure about 1.5 mi. southeast of first locality (NW.¼ sec. 1, Twp. 13, Rge. 2).

In both cases the material collected came from the upper 10 feet of the Gunn Member, for the underlying portion is not exposed. Loose fossils are abundantly represented in the weathered road cut where the rock appears quite shaly and oxidized to a reddish color. In the quarry exposure, the lithology is a somewhat nodular limestone with iron oxide for the most part just on the surface. The contact with overlying Penitentiary Dolomite is distinct.

Faunal assemblage.—A fairly large number of conodonts has been recovered from acetic acid residues of Stony Mountain argillaceous limestones. Some forms are represented by but few specimens, but in others, such as *Panderodus*, no effort was made even to tabulate the number observed. The following are represented:

Belodina inclinata (Branson & Mehl)
B. leithi Ethington & Furnish, n. sp.
B. profunda (Branson & Mehl)
B. sp.
Cordylodus robustus Ethington & Furnish
Cyrtoniodus complicatus Stauffer
C. sinclairi Ethington & Furnish, n. sp.
Dichognathus typica Branson & Mehl
Drepanodus homocurvatus Lindström
D. suberectus (Branson & Mehl)
Eoligonodina ulrichi Stone & Furnish
Oistodus excelsus Stauffer
?Oulodus sp.
Ozarkodina concinna Stauffer
Panderodus angularis (Branson, Mehl & Branson)
P. compressus (Branson & Mehl)
P. gracilis (Branson & Mehl)
P. intermedius (Branson, Mehl & Branson)
P. panderi (Stauffer)
Phragmodus undatus Branson & Mehl
Plectodina dilata Stauffer

Plegagnathus nelsoni Ethington & Furnish
?*Prioniodina* sp.
Pristognathus bighornensis Stone & Furnish
Subcordylodus delicatus (Branson & Mehl)
Trichonodella cf. *T. flexa* Rhodes
T. spp.

Significance.—Only a few of the some 30 conodont species identified from the Stony Mountain have any particular stratigraphic importance. About two-thirds of the species make-up is the same as that described from the upper Bighorn Formation (Stone & Furnish, 1959), considered to represent a direct continuity although situated some 600 miles to the southwest. Numerically, the proportion of species in common would be considerably greater; by far the most abundant genus is *Panderodus* in both areas. Another conodont fauna which is comparably similar is that from the Shammattawa Limestone of northern Manitoba (Ethington & Furnish, 1959). This deposit is separated by about 200 miles of crystalline rocks from the central Manitoba outcrop belt. The known species from the Maquoketa Formation of Iowa, Missouri, and Kansas (Branson & Mehl, 1933; Imbt, 1941; and Glenister, 1957) are equally close to those of the Stony Mountain (Table 1).

TABLE 1—Stony Mountain and related conodont faunas.

	Stony Mtn.	Maquoketa	Shammattawa	U. Bighorn
Ambalodus triangularis		×	×	×
Belodina inclinata	×	×		
B. leithi	×			
B. profunda	×	×	×	×
Cordylodus robustus	×		×	
Cyrtoniodus complicatus	×	×	×	×
C. sinclairi	×			×
Dichognathus typica	×	×		
Drepanodus homocurvatus	×	×	×	×
D. suberectus	×	×		×
Eoligonodina ulrichi	×			×
Oistodus excelsus	×	×		×
Oulodus sp.	?		×	×
Ozarkodina concinna	×	×	×	
Panderodus angularis	×			
P. compressus	×		×	
P. gracilis	×	×	×	×
P. intermedius	×	×		×
P. panderi	×	×	×	×
Phragmodus undatus	×	×		
Plectodina dilata	×		×	
Plegagnathus nelsoni	×		×	
P. dartoni			×	×
Prioniodina sp.	?	×	×	×
Pristognathus bighornensis	×			×
Subcordylodus delicatus	×	×		
Trichonodella spp.	×	×	×	×

Similarity of the Bighorn and Gunn faunas is emphasized by the mutual occurrences of *Eoligonodina ulrichi*, *Pristognathus bighornensis*, and *Cyrtoniodus sinclairi*. *Cordylodus robustus* is previously known only from the Shammattawa. All these species appear to be quite distinctive, and they may prove to be of considerable stratigraphic significance for correlation. *Plegagnathus nelsoni* occurs in the Shammattawa and Gunn but not in the Bighorn. A closely related species, *P. dartoni* (Stone & Furnish), common to both the Shammattawa and Bighorn, is not included in the Gunn fauna. *Belodina profunda*, previously known from the Maquoketa of Missouri and Kansas, is also prominent in the faunas of the upper Bighorn, Stony Mountain, and Shammattawa.

Panderodus is the dominant element of the Gunn, Shammattawa, Bighorn, and upper Maquoketa faunas. Such a condition has been considered to indicate Richmondian age (Rhodes, 1955, p. 121) although the genus is of long range and widespread distribution in the Ordovician and Silurian. Except for the relative abundance of *Panderodus*, these faunas have only a few genera in common with the type Richmondian.

Collectively the fauna of the Gunn Member of the Stony Mountain Formation is closest to those of the upper Bighorn and Shammattawa. Although it holds many species in common with the Maquoketa, most of these are long ranging and of little stratigraphic value. Nevertheless, the common occurrence of *Belodina profunda* and *B. inclinata* probably is significant. An Upper Ordovician age is indicated for these faunas, particularly because of the presence of *Ambalodus* which occurs in all but the Stony Mountain. Absence of *Rhipidognathus*,

Aphelognathus, and *Zygognathus*, unique genera which characterize the conodonts of the type Richmondian, suggests the Stony Mountain and related faunas may correlate with part of the older Cincinnatian. The conodonts of the latter portion of the standard section have been described (Sweet *et al.*, 1959) since the submission of the present manuscript. As these authors suggest (1959, p. 1038) an assignment of the Stewartville-Dubuque faunas of the Upper Mississippi Valley to early Edenian, and the greater portion of the Maquoketa Formation to late Edenian and lower Maysvillian, now appears logical. Nevertheless, generalizations involving precise age comparisons of Upper Ordovician faunas from the Rockies and sub-Arctic with those of the Eastern Interior still seem somewhat obscure. According to their stated conclusions on known conodont ranges, the Stony Mountain fauna can be regarded as pre-Richmondian, probably Maysvillian; a possibility of early Richmondian must also be considered.

New information is now available on related conodont faunas from the type Caradocian section of Wales (Lindström, 1959) which supplements Rhodes' (1955) earlier work. This new study reiterates, however, that a great deal more information is still needed before intercontinental Ordovician correlation by conodonts can be secure.

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SYSTEMATIC PALEONTOLOGY

Genus BELODINA Ethington, 1959

Type species: *Belodus grandis* Stauffer, 1935.

BELODINA INCLINATA (Branson & Mehl)

Pl. 38, fig. 13

Belodus inclinatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 125,126, pl. 10, fig. 24; FAY, 1952, Univ. Kansas Paleont. Contrib., Vertebrata, art. 3, p. 67.

Remarks.—A single specimen is closely comparable to Branson & Mehl's illustration and description of the holotype from the Maquoketa of Missouri. Development of the characteristic offset shoulder may indicate a relationship to *Belodina kirki* Stone & Furnish from the upper Bighorn of Wyoming. In the latter species, however, such a flange is prominent on both sides of the unit. *Belodina inclinata* has also been reported from the Maquoketa in subsurface in central Kansas.

Repository.—Figured hypotype, S.U.I. 10291.

BELODINA LEITHI Ethington & Furnish, n. sp.

Pl. 38, fig. 12

This species is based on a single, distinctive specimen having a high base and long slender, reclined cusp. The outer side is slightly convex from base to tip of cusp; the inner side concave. A prominent ridge, subparallel to the aboral margin of the unit, extends from the base to the tip of the cusp on both the inner and outer sides. Aboral edge of the unit is sharp. Oral edge bears five distinct, sharp-edge denticles which are fused throughout the greater part of their length. The denticles are set into the oral part of the unit to a depth nearly equal to their free length. There is a regular increase in size of the denticles in the series in an anterior direction. The basal cavity bifurcates anteriorly with the longer fork reaching to the base of the most anterior denticle.

Remarks.—The general configuration and base of *Belodina leithi* are typical of previously known species. In outline it is closest to *B. grandis* (Stauffer), but differs from the latter species in the ornamentation of the lateral faces and in the variation in

size of denticles. The long slender cusp is similar to that of *B. compressus* from the Icebox Shale (Furnish, Barragy & Miller, 1936), but the denticulation of *B. leithi* is distinctly different. Longitudinal ridges on the lateral faces are similar to those of *B. dispansa* (Glenister) and suggestive of a trend culminating in forms such as *B. kirki* Stone & Furnish and *B. inclinata* (Branson & Mehl).

Repository.—Figured holotype, S.U.I. 10292.

BELODINA PROFUNDA (Branson & Mehl)
Pl. 38, figs. 10,11

Belodus profundus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 125, pl. 10, fig. 25.
Belodina profunda STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 221, pl. 31, figs. 16,17; ETHINGTON & FURNISH, 1959, Jour. Paleontology, p. 541,542, pl. 73, fig. 5.

Remarks.—This species is the most abundant non-distacodid element in the Stony Mountain fauna. About half the specimens bear three denticles, the other half only two. Stone & Furnish (1959) observed the same variation among Bighorn specimens of *B. profunda*. Those having only two denticles are identical to the specimens from the Shammattawa of the Hudson Bay Lowland described by Ethington & Furnish (1959). One of the latter (Pl. 38, fig. 10) is refigured here for comparison.

Repository.—Figured hypotype S.U.I. 10293, unfigured hypotype S.U.I. 10294.

Genus CORDYLODUS Pander, 1856
Type species: *C. angulatus* Pander, 1856.

CORDYLODUS ROBUSTUS Ethington & Furnish

Cordylodus robustus ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541,543, pl. 73, fig. 11.

Remarks.—The only representative of this species was recovered from the City of Winnipeg Quarry. It is identical to the holotype from the Shammattawa in all respects except size.

Repository.—Unfigured hypotype S.U.I. 10296.

Genus CYRTONIODUS Stauffer, 1935
Type species: *C. complicatus* Stauffer, 1935.

CYRTONIODUS COMPLICATUS Stauffer

Cyrtoniodus complicatus STAUFFER, 1935, Geol. Soc. America, Bull., v. 46, p. 140,158, pl. 11 figs. 44,46,48–51; STONE & FURNISH, 1959 [part], Jour. Paleontology, v. 33, p. 221,222, pl. 31, fig. 9; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 274, pl. 40, fig. 7; ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541, pl. 73, fig. 4.

Remarks.—Material referred to this species is robust, but in all other respects identical to previously described forms from Middle and Upper Ordovician rocks of North America.

Repository.—Unfigured hypotype, S.U.I. 10297.

CYRTONIODUS SINCLAIRI Ethington & Furnish, n. sp.
Pl. 38, fig. 16

Cyrtoniodus complicatus STONE & FURNISH, 1959 [part], Jour. Paleontology, v. 33, p. 221–222.

This species includes forms having a posterior denticulate bar, large cusp, and denticulate anticusp. The cusp is wide, sharp-edged, with broadly convex lateral faces, and turned slightly inward from the plane of the posterior bar. The distal portion is broken away on all specimens obtained, but projection of the stump suggests that the cusp was much longer than the denticles of the posterior bar. The bar is low, broad, and bears a series of sharp-edged, partially fused denticles which are inclined posteriorly. The angle of inclination increases posteriorly in the series. All specimens are broken posteriorly, and the number of denticles on the most nearly complete bar is four. The anticusp is in the plane of the cusp. The inner side of the anticusp near the anterior edge carries one or two peg-like denticles or nodes whose orientation is normal to the plane of the anticusp. Base of the unit flares inward at the junction of the bar, cusp and anticusp. Although filled with phosphatic material on all the specimens, the basal cavity appears to penetrate anteriorly to a point beneath the cusp and to be continued posteriorly as a groove beneath the bar.

Remarks.—With the exception of the denticles on the anticusp and general robustness, the overall configuration of these forms is very similar to material identified as *C. complicatus*. The low denticles on the anticusp are suggestive of Decorah specimens which Stauffer (1935, pl. 75, figs. 15,16) identified as *Ptiloconus* [=*Pteroconus*] *ro-*

bustus. Several specimens from the upper Bighorn of northern Wyoming, identified by Stone & Furnish (1959) as *C. complicatus* but not figured, are identical with *C. sinclairi*.

Repository.—Figured holotype, S.U.I. 10298.

Genus DICHOGNATHUS Branson & Mehl, 1933

Type species: *D. primus* Branson & Mehl, 1933.

DICHOGNATHUS TYPICA Branson & Mehl

Dichognathus typica BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 113, pl. 9, figs. 27–29; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 274, pl. 40, fig. 17.

Remarks.—Several fragmental specimens were recovered. They appear to conform closely to *D. typica*, a form previously reported in Upper Mississippi Valley strata ranging from Glenwood through Maquoketa.

Repository.—Unfigured hypotype, S.U.I. 10299.

Genus DREPANODUS Pander, 1856

Type species: *D. arcuatus* Pander, 1856.

DREPANODUS HOMOCURVATUS Lindström

Drepanodus homocurvatus LINDSTRÖM, 1954, Geol. Fören. Förhandl., Bd. 76, p. 563, pl. 3, figs. 23,24,39; STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 222, pl. 31, fig. 8; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 276, pl. 39, fig. 16; ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541.

Remarks.—This form is the next most abundant element in the fauna after the various species of *Panderodus*. It is almost ubiquitous in Middle and Upper Ordovician faunas of North America and Europe.

Repository.—Unfigured hypotype, S.U.I. 10300.

DREPANODUS SUBERECTUS (Branson & Mehl)

Oistodus suberectus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 111, pl. 9, fig. 7.
Drepanodus suberectus STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 222, pl. 31, fig. 7; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 276, pl. 39, fig. 17.

Remarks.—Stony Mountain material is identical to that previously reported from the Bighorn and various Middle and Upper Ordovician units in the Upper Mississippi Valley. Like *D. homocurvatus*, with which it generally occurs, this is a long ranging species.

Repository.—Unfigured hypotype, S.U.I. 10301.

Genus EOLIGONODINA Branson, Mehl & Branson, 1951

Type species: *E. robusta* Branson, Mehl & Branson, 1951.

EOLIGONODINA ULRICHI Stone & Furnish

Pl. 38, figs. 2,3

Eoligonodina ulrichi STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 222, pl. 32, figs. 16–18.

Remarks.—Gunn Member forms compare closely to the types from the upper Bighorn of Wyoming in all respects except size. Although Bighorn material is somewhat larger, the general proportions are the same in both faunas.

Repository.—Figured hypotypes, S.U.I. 10302, 10303.

Genus OISTODUS Pander, 1856

Type species: *O. lanceolatus* Pander, 1856.

OISTODUS EXCELSUS Stauffer

Oistodus excelsus STAUFFER, 1935, Jour. Paleontology, v. 9, p. 610, pl. 74, fig. 43; STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. p. 224, pl. 31, fig. 5; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 282, pl. 39, fig. 20.

Remarks.—This species is a widely distributed, long ranging form. Those found in the lower Stony Mountain are identical to the other Middle and Upper Ordovician occurrences.

Repository.—Unfigured hypotype, S.U.I. 10304.

Genus OULODUS Branson & Mehl, 1933

Type species: *O. mediocris* Branson & Mehl, 1933.

?OULODUS sp.

Pl. 38, fig. 15

A single fragmented specimen is very close to the Bighorn material which Stone & Furnish described as *Oulodus mediocris*. It differs from *O. rohneri* Ethington & Furnish of the Shammattawa in the cross sectional shape of the denticles and their spacing.

Repository.—Figured specimen, S.U.I. 10305.

Genus OZARKODINA Branson & Mehl, 1933
Type species: *O. typica* Branson & Mehl, 1933.

OZARKODINA CONCINNA Stauffer

Ozarkodina concinna STAUFFER, 1935, Geol. Soc. America, Bull., v. 46, p. 148, pl. 10, figs. 41,45, 46; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 283, pl. 41, figs. 15,16; ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541.

Remarks.—*Ozarkodina concinna* occurs in lesser abundance in the Manitoba faunas than it does in the Ordovician of the Upper Mississippi Valley. No complete specimens were recovered from the Gunn Member, but the fragmented representatives are in complete agreement with those previously known.

Repository.—Unfigured hypotype, S.U.I. 10306.

Genus PANDERODUS Ethington, 1959
Type species: *Paltodus unicostatus*, Branson & Mehl, 1933.

PANDERODUS spp.

Remarks.—This genus comprises the bulk of the fauna of the Gunn Member. Wide variations in form are represented, and these have been referred to five species, all previously known, which encompass the range of characters. More than half of the specimens fall within the limits of *P. gracilis*, whereas the remainder are nearly uniformly distributed among *P. angularis*, *P. compressus*, *P. intermedius* and *P. panderi*.

Repository.—Unfigured hypotypes, S.U.I. 10307, 10308, 10309, 10310, 10311.

Genus PHRAGMODUS Branson & Mehl, 1933
Type species: *P. primus* Branson & Mehl, 1933.

PHRAGMODUS UNDATUS Branson & Mehl
Pl. 38, fig. 4

Phragmodus undatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 115,116, pl. 8, figs. 22–26; ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 285–286, pl. 41, fig. 12.

Remarks.—Two specimens compare closely to the Upper Mississippi Valley forms which range from Plattin through Maquoketa.

Repository.—Figured hypotype, S.U.I. 10312.

Genus PLECTODINA Stauffer, 1935
Type species: *P. dilata* Stauffer, 1935.

PLECTODINA DILATA Stauffer
Pl. 38, fig. 7

Plectodina dilata STAUFFER, 1935, Geol. Soc. America, Bull., v. 46, p. 152,160, pl. 11, figs. 43,47; ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541,544, pl. 73, fig. 11.

Remarks.—A number of specimens compare closely with the Shammattawa material referred to this species. However, the Stony Mountain forms are smaller than those from northern Manitoba.

Repository.—Figured hypotype, S.U.I. 10313.

Genus PLEGAGNATHUS Ethington & Furnish, 1959
Type species: *P. nelsoni* Ethington & Furnish, 1959.

PLEGAGNATHUS NELSONI Ethington & Furnish
Pl. 38, fig. 1

Plegagnathus nelsoni ETHINGTON & FURNISH, 1959, Jour. Paleontology, v. 33, p. 541,544–545, pl. 73, figs. 2,3.

Remarks.—Material identified as *P. nelsoni* is moderately abundant in the Gunn fauna. Most specimens are broken but all conform to the holotype from the Shammattawa.

Repository.—Figured hypotype, S.U.I. 10314.

Genus PRIONIODINA Ulrich & Bassler, 1926
Type species: *P. subcurvata* Ulrich & Bassler, 1926.

?PRIONIODINA sp.
Pl. 38, fig. 14

Remarks.—Several fragmented specimens are tentatively placed in *Prioniodina*. All have laterally compressed, partially fused denticles, a character which is not typical of the genus. In this respect they stand close to Bighorn forms identified as *Ozarkodina delecta* by Stone & Furnish.

Repository.—Figured specimen, S.U.I. 10315.

Genus PRISTOGNATHUS Stone & Furnish, 1959

Type species: *P. bighornensis* Stone & Furnish, 1959.

PRISTOGNATHUS BIGHORNENSIS Stone & Furnish

Pl. 38, figs 8,9

Pristognathus bighornensis STONE & FURNISH, 1959, Jour. Paleontology, v. 33, p. 226–227, pl. 32, figs. 7,8.

Remarks.—Abundant specimens, several nearly complete, have been recovered from Gunn shale. All are somewhat more slender than the types from the upper Bighorn, but in other aspects, the specimens from both areas are identical.

Repository.—Figured hypotype, S.U.I. 10316.

Genus SUBCORDYLODUS Stauffer, 1935

Type species: *S. elongatus* Stauffer, 1935.

SUBCORDYLODUS DELICATUS (Branson & Mehl)

Cordylodus? delicatus BRANSON & MEHL, 1933, Missouri Univ. Studies, v. 8, p. 129, pl. 10, figs. 14,15.

Subcordylodus delicatus ETHINGTON, 1959, Jour. Paleontology, v. 33, p. 288, pl. 41, fig. 13.

Remarks.—A single specimen was recovered. This species is common in Middle and Upper Ordovician faunas of the United States and has been reported from the Llandeilo Limestone of Wales.

Repository.—Unfigured specimen, S.U.I. 10317.

Genus TRICHONODELLA Branson & Mehl, 1948

Type species: *Trichognathus prima* Branson & Mehl, 1933.

TRICHONODELLA cf. T. FLEXA Rhodes

Remarks.—Numerous fragments are comparable to previously reported occurrences of *Trichonodella flexa*. The species is known from the upper Galena and the Maquoketa in the Upper Mississippi Valley and from the Llandeilo Limestone of Wales.

Repository.—Unfigured specimen, S.U.I. 10318.

TRICHONODELLA spp.

Pl. 38, figs. 5,6

Remarks.—A variety of individuals in the Gunn fauna belongs in this genus. None appears to fit previously described species. Two specimens are figured, one of which (fig. 6) probably is a juvenile form.

Repository.—Figured specimens, S.U.I. 10319, 10320. Unfigured specimen, S.U.I. 10322.

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AIR BRUSH FOR WHITENING FOSSILS, AND NOTES ON PHOTOGRAPHY

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ABSTRACT—The use of a commercially available air brush for whitening fossils prior to photography is suggested as an advantageous technique. Other procedures that have been found useful in rapidly obtaining photographs of large suites of macrofossils are reviewed briefly.

PALEONTOLOGISTS who are concerned with the study and photography of fossils long have recognized the notable improvement in surface detail that accompanies the coating of the fossils with a white, non-reflecting substance. Such a surficial coating of white ammonium chloride can be obtained by blowing a mixture of the fumes of concentrated hydrochloric acid and of ammonium hydroxide on specimens (Bassler, 1953, p. G20,G21) or by similarly directing the fumes from heated ammonium chloride powder (Teichert, 1948) or antimony (Poulsen, 1957, p. 1029). Another procedure is to manipulate specimens in the magnesium oxide rising from burning magnesium ribbon (Rasetti, 1947, p. 397,398) or magnesium filings.

A continuing program that involves the preparation of photographs for a number of plates similar to those issued annually in this Journal has necessitated the adoption or development of rapid and consistent methods for preparing and photographing fossils. Although many of the techniques reviewed here are in use by others, the routine procedure is summarized as an aid to those not now experienced in the photography of macrofossils.

The fossils are first prepared and cleaned and are then washed with acetone to remove any traces of grease or oil. They are coated with black India ink to give a uniform tone. This inking eliminates the need for separately estimating exposures for a succession of differently colored specimens. The black background also emphasizes the shadowed depressions as is noted later. Moreover, morphologically insignificant color variations on specimens are concealed (pl. 39, figs. 1a,1b). Some uniformly colored fossils, however, such as the specimens from the Miocene *Ecphora* beds of Florida having a chalky or lusterless white surface, need not be inked or whitened.

For whitening fossils in Houston the ammonium chloride procedure is unsatisfactory because the consistently high humidity causes the sublimate to form into grainy clumps. Magnesium ribbon that is burned to produce magnesium oxide which is directed onto the surface of a fossil is effective in whitening specimens. The odor of the fumes is objectionable, however, and air currents which disperse the oxide prevent using the setup under a hood. Moreover, considerable difficulty is encountered in obtaining a precise distribution of the whitening in the rising magnesium oxide.

An air brush of the conventional type used in art and poster work has been found to be very advantageous in applying a surficial whitening. A strained mixture of 1 part powder (magnesium oxide, Bon Ami, and similar materials have been used with about equal success) and 20 parts of alcohol is used. The mixture must dry very rapidly to prevent flowage. Fossils are mounted on a prism of modeling clay so that handling of the specimen can be avoided, and the nozzle of the air brush is held about two inches from the specimen. At about this distance the placement of the coating can be controlled by using broad strokes of the nozzle. After a little practice, fossils can be whitened in five to ten seconds. Following a spray of this duration, the coating is permitted to dry (the coating is not distinct until the alcohol evaporates) for about one minute before determining the need for additional spraying. The air-brush coating seems finer in texture and more nearly uniform that that which was obtained using magnesium smoke, and the air-brush method involves less practice

and time. The whitening persists for several days if specimens are not handled.

Experience indicates that the whitening can be placed so as to emphasize surficial detail and not merely to coat the surface thinly and evenly. Uniform inking is adequate to conceal any color differentiation (pl. 39, figs. 1a,b), and the whitening can serve to accent detail. Generally the spray is directed normal to major surface ornamentation and with the part of the fossil to be oriented at the upper left of the photograph towards the nozzle. The very thin white to light gray coating then emphasizes the shadows by coating the highlighted sides of depressions without covering the black on the parts of the depressions that are to be shown as shadows (pl. 39, figs. 1a,b). The coating thus serves to increase the contrast (pl. 39, figs. 2a,b); it also tends to eliminate reflected glare from the brightly lighted parts of the specimen (pl. 39, figs. 3a,b).

The inked and coated fossils are photographed rapidly using a 35-mm. camera and accessories. A 50-mm. lens and a bellows seem adequate for most specimens, but a telephoto lens (as 135 mm.) decreases the distortion in large fossils. This phase is facilitated by consistent placement of the light sources. The main light (75-watt clear glass spot) is conventionally located at a horizontal distance of about 1.5 feet from the specimen or so as to avoid strong reflections from surfaces closest to the light. The light is raised (slightly for flat specimens and higher for thick fossils) so that the beam just skims the upper surface. A fill-in or back light (75-watt frosted bulb) is located opposite the main light and somewhat farther away from the specimen. It is elevated less than the main light. The back light serves merely to lighten the dark shadows so that details are evident. Parabolic reflectors are used on both lights.

Most of the photography is concerned with specimens that are substantially less than well preserved. The methods outlined above with occasionally some minor experimentation, however, yield adequate photographs with only moderate expenditure of time. Adequate preparation of specimens together with consistently well selected lighting and photographic procedures avoids the need for retouching the prints. It has been noted, however, that careless or inadequate preparatory and photographic techniques can readily result in prints that have many of the objectionable attributes commonly ascribed to retouched photographs.

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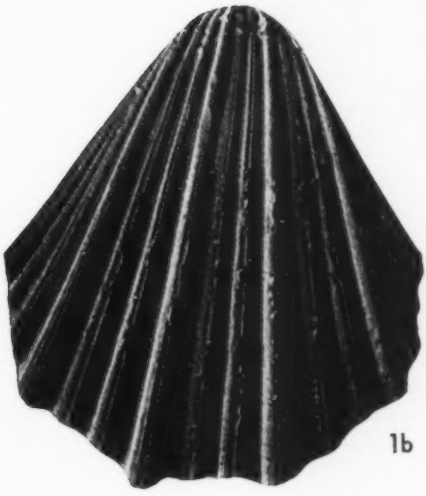
EXPLANATION OF PLATE 39

FIG. *1*—Views of a Tertiary pectenoid showing the confusing effect of color variation (*a*) and the increased clarity after inking and whitening (*b*). The ornamentation is highlighted by selectively concentrating the whitening. ×1.5.

2—Views of an Ordovician spiriferoid brachiopod illustrating the effect of inking and whitening in depicting major and minor surface features. The untreated specimen (*a*) has glare at the upper left; the treated specimen (*b*) suggests more accurately the nature of the ribs and sinus. ×2¼.

3—Views of a Pennsylvanian brachiopod showing the increase in detail that accompanies inking and whitening. ×1¼.

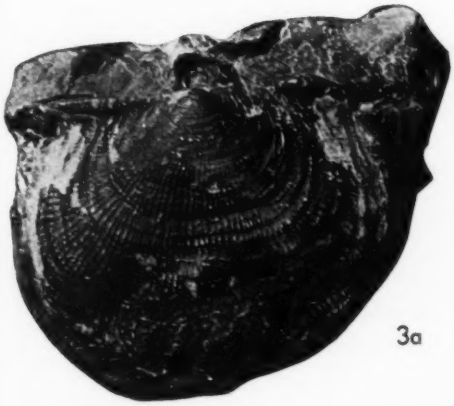
1a



1b

2a

2b

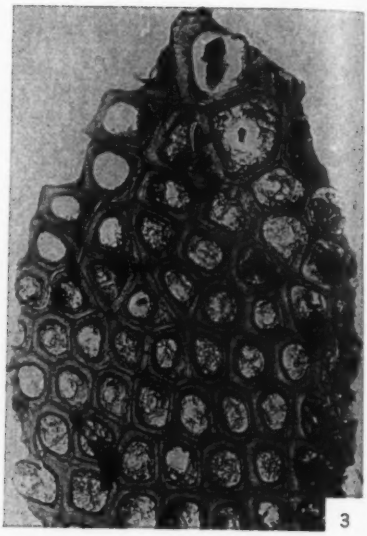


3a

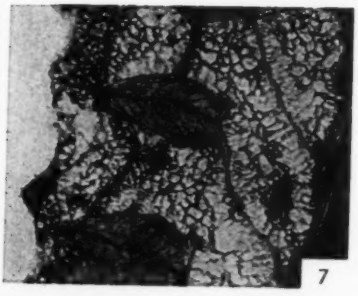
3b

1

2


3

4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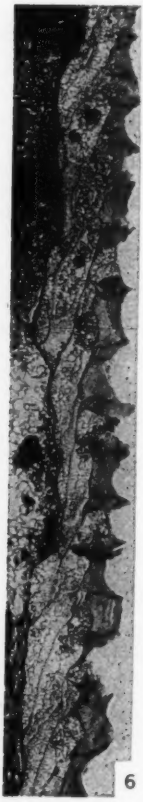
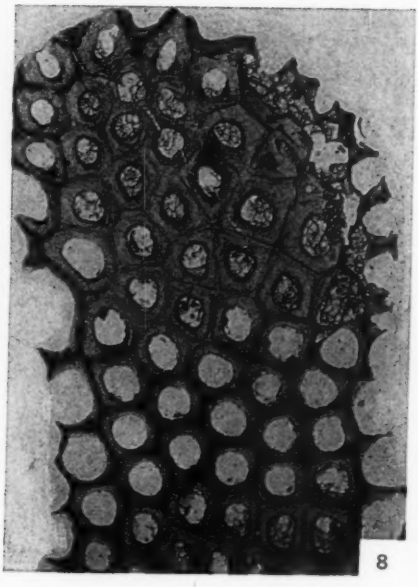

6

5


8

JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 277–279, PL. 40, MARCH, 1960

LECTOTYPE OF *ANISOTRYPA SYMMETRICA* ULRICH

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ABSTRACT—A lectotype and lectoparatypes are selected for *Anisotrypa symmetrica* Ulrich, the type species of the bryozoan genus *Anisotrypa* Ulrich. The original specific description of *Anisotrypa symmetrica* is expanded.

INTRODUCTION

WHILE studying Golconda (middle Chester) bryozoans, the writers were impressed by structural similarities of some specimens to both *Anisotrypa* Ulrich and *Tabulipora* Young. In tangential section, some specimens of *Tabulipora* closely approach *Anisotrypa* as they show small sparsely developed acanthopores which might be overlooked readily in cursory examination; further, the acanthopores in these specimens are commonly restricted to the outermost region of the zoarium as they are not observed in moderately deep tangential sections. In longitudinal section, some specimens of *Tabulipora* are reminiscent of *Anisotrypa* as they have short zooecia showing rather poorly defined monilae and containing sparingly developed centrally perforate diaphragms. In *Anisotrypa*, zooecia of above average length in local areas of the zoarium differ from those of *Tabulipora* in lacking distinct monilae.

The structural similarity between *Tabulipora* and *Anisotrypa* was noted by Ulrich (1890, p. 447) who stated, concerning the close relationship between *Anisotrypa* and *Stenopora* (=*Tabulipora* of modern usage): "This relationship seems quite remote when we compare only typical species of the genera, but becomes rapidly less distant with the extensions of our comparisons, so that now the only structures that are not in common to the two genera are the acanthopores. These are wanting in *Anisotrypa*."

During our work on Golconda bryozoans, the writers examined type material of *Anisotrypa symmetrica* Ulrich, the type species of the genus. Herein a lectotype for *A. symmetrica* is selected, and the original description of the species expanded. The types were made available for study through the kindness of R. S. Boardman, Associate Curator of Invertebrate Paleontology and Paleobotany, United States National Museum, who also advised on type designations for the specimens. Photographs were taken by George Ringer of the Indiana Geological Survey.

The following facts pertain to the type specimens of *Anisotrypa symmetrica:*

1. Ulrich (1883, p. 277) did not designate the status of his type specimens in his original specific description, but the label accompanying the type material indicates that the specimens are cotypes.
2. The type material, as stated in the original description, was collected from Grayson Springs (Grayson County,

EXPLANATION OF PLATE 40

Fig. 4, ×4; fig. 7, ×60; all others, ×20

FIGS. *1–3*—Lectotype, *Anisotrypa symmetrica* Ulrich. *1,2*, Longitudinal sections of opposite sides of hollow branch, USNM 43412; *3*, Tangential section, USNM 43412.
4—Lectoparatype, *A. symmetrica*, exterior of zoarium, USNM 137956.
5–7—Lectoparatype, *A. symmetrica*, USNM 43412-2. *5,6*, Longitudinal sections from opposite sides of hollow ramose zoarium; *7*, Enlargement of part of *5*, showing nature of zooecial wall.
8—Lectoparatype, *A. symmetrica*, USNM 43412-1. Tangential section.

Kentucky) and Tateville (Pulaski County, Kentucky).

3. The box containing the type specimens includes a label which reads "cotypes and hypotype, Chester group, Sloans Valley, 43412, 43631." Sloans Valley is less than five miles from Tateville. It is not possible to distinguish the hypotype as the individual specimens are not numbered. One fragmentary zoarium bears a green rhomb; this specimen is described externally herein and is selected as a lectoparatype of the species. This specimen illustrates best the external features of *A. symmetrica* described and figured by Ulrich (1883, p. 276, pl. 13, fig. 5).
4. Two slides, here designated as lectotype and each bearing the label "type section, *Anisotrypa symmetrica* Ulrich, Chester gr., Sloans Valley, Ky., 43412," have an affixed black rhomb. It should not necessarily be assumed that these slides were prepared from the fragmentary zoarium bearing the green rhomb. These slides cannot be correlated with absolute certainty with Ulrich's figured sections (1883, pl. 13, figs. 5b,c), but the agreement is sufficiently close so that the concept of the species is not affected. The writers have studied specimens and thin sections, recently prepared at the United States National Museum, of three of Ulrich's cotypes; one of the specimens (USNM 43412-3) must be rejected as it shows very conspicuous acanthopores and is undoubtedly a species of *Tabulipora*.

The description of the lectotype follows.

LECTOTYPE, *ANISOTRYPA SYMMETRICA*

Pl. 40, figs. 1–3

Tangential section.—Zooecia sharply angular, commonly pentagonal or hexagonal, rarely quadrate, and arranged sublinearly in intermonticular areas; zooecial apertures subround or broadly ovate, averaging 0.23 mm. in maximum diameter but ranging from 0.19 to 0.32 mm. for 20 measurements; typically (11 of 15 measurements) five entire zooecia and part of sixth in 2 mm., measuring nearly parallel to length of zoarium; less commonly (4 of 15 measurements) six entire zooecia and part of seventh in this distance. Zooecial wall thick, consisting of obscure microlaminae concentric about zooecial apertures, and showing conspicuous divisional line between zooecia; average wall thickness (based on 20 measurements) 0.13 mm., ranging from 0.08 to 0.22 mm. Monticule somewhat incomplete, consisting of a central, large, imperfectly hexagonal zooecium irregularly surrounded by zooecia of smaller size and one conspicuously large zooecium. Acanthopores and mesopores lacking.

Longitudinal section.—Zoarium consisting of two layers, the outer thin and incomplete; thin-walled zooecia in immature zone of each layer oriented in opposite directions. In immature region, zooecia inclined and thin-walled; base of mature region marked by abrupt increase in wall thickness; zooecia bend sharply toward zoarial surface where immature portion of zooecia is short and curve more gradually to surface where zooecia display a longer immature region. In mature region, zooecial wall structure of $\wedge$-shaped laminae whose apices are directed outward; clearly marked dark-colored divisional line passes through apices of wall laminae. Diaphragms rare or lacking in lower immature zone but generally two centrally perforate diaphragms in remainder of zooecia; where immature region is long, both diaphragms are at distal end of this region; where short, one diaphragm at distal part of immature zone and one in mature region, or a single diaphragm in the mature zone; where immature region short, lower centrally perforate diaphragm attached at one end to basal corner of thickened zooecial wall and at other end to thin wall of distal immature region; under high magnification ($\times 210$), wall laminae continuous into diaphragms.

Remarks.—The lectoparatypes (Pl. 40, figs. 5–8) do not differ appreciably from the lectotype in tangential section. In longitudinal section, the zooecia are inclined in the immature region, the degree of inclination varying from a steep, high-angled slope where the immature region is well developed to a nearly recumbent attitude where this region is thinner. Where the

zoarial growth is thin, the zooecia rapidly become erect; where thick, the zooecia bend more gradually to the zoarial surface. The length of the immature portion of a zooecium equals, or more usually exceeds, the length of the mature region.

Fragments of the sectioned lectoparatypes are too small to merit external description.

Repository of lectotype.—USNM thin sections 43412.

The external description of the lectoparatype (USNM 137956, Pl. 40, fig. 4) follows: Fragment of hollow ramose zoarium 10 mm. long and 7 mm. in maximum diameter; maximum observed thickness of zoarial growth 1 mm. but usually somewhat less than 1 mm. Zooecia thick-walled, four-, five-, or six-sided, and sharply angular. Monticules somewhat variable in elevation and inclination, composed of a centrally located unusually large zooecium flanked by zooecia very slightly above average in size; monticules spaced 3 to 4 mm. apart, measuring from center to center and parallel to length of zoarium; monticules 3 mm., rarely 3.5 mm., apart measured from center to center and transverse to length of zoarium; monticules arranged linearly or sublinearly parallel to length of zoarium; large zooecium in monticular center 0.9 mm. wide. Acanthopores and mesopores absent.

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JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 280–284, PL. 41, MARCH, 1960

BURDIGALIAN OSTRACODA FROM THE SURAT-BROACH AREA, WESTERN INDIA

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ABSTRACT—Fourteen species of Ostracoda are recorded and illustrated from the Miocene (Burdigalian) of the Surat-Broach area, Western India. These include one new species—*Actinocythereis levinsoni*. The fauna shows affinities with both the European and the Indo-Pacific forms.

INTRODUCTION

THIS paper is a sequel to an earlier paper by the authors (Bhatia & Mandwal, 1957) on the smaller Foraminifera from the Agate conglomerates of the Surat-Broach area, Western India. The sample from which the present suite of ostracodes is described was collected by Prof. S. R. N. Rao during the field seasons 1937–1941. The larger Foraminifera from this horizon have already been described by Rao (1939) and Rao & Singh (1956); the smaller Foraminifera by Bhatia & Mandwal (*op. cit.*). For details concerning the stratigraphy of the area, reference may be made to works by Rao (1941) and Rao & Singh (*op. cit.*).

Fourteen species of Ostracoda are recorded and illustrated here; these include one new species—*Actinocythereis levinsoni*. A check list is given below:

Bairdia amygdaloides Brady
Paracypris sp. indet.
Paracytheridea sp. indet.
Cytherura sp. indet.
Actinocythereis levinsoni, n. sp.
?Bradleya sp. indet.
Hermanites aff. *H. haidingeri* (Reuss)
Aurilla cicatricosa (Reuss)
Loxoconcha punctatella (Reuss)
?Cytheromorpha sp. indet.
Krithe papillosa (Bosquet)
Cytherella compressa (von Münster)
?Cytherelloidea sp. indet.
Cytherelloidea aff. *C. cingulata* (Brady)

PREVIOUS WORK

Little or no work has so far been done on the Tertiary Ostracoda of India. The only paper which refers to some Ostracoda from the Miocene of India is the one by Jacob & Sastri (1953). Though the paper deals mainly with Foraminifera from the Miocene beds at Chavara, near Quilon, Travancore, a few Ostracoda are also mentioned as being present. These are *Bairdia amygdaloides* Brady, *B.* cf. *foveolata* Brady, *?Cytherella* sp., and *Loxoconcha* sp.

The few specimens of each of the species described in this paper made it difficult to identify them even at the generic level. However, this paper does provide an opportunity to record the types of ostracodes that occur in the Miocene section of Western India.

ACKNOWLEDGMENTS

The authors wish to take this opportunity to express their profound gratitude to Stuart A. Levinson, Humble Oil & Refining Company, Houston, Texas, for his many helpful suggestions and also for his painstaking work in checking the manuscript. Because of the scarcity of material, it was possible for him actually to examine only the specimens of the new species of *Actinocythereis*. The authors are also indebted to S. R. N. Rao for the loan of the material.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latrelle 1806
Suborder PODOCOPA Sars, 1866
Family BAIRDIIDAE Sars, 1887
Subfamily BAIRDIINAE Sars, 1923
Genus BAIRDIA M'Coy, 1844
BAIRDIA AMYGDALOIDES Brady
Pl. 41, fig. 1

Bairdia amygdaloides BRADY, 1865, Trans. Zool. Soc. London, v. 5, p. 364, pl. 57, figs. 6a–c; ——, 1880, Rept. Voy. Challenger, Zool., v. 1, pt. 3, p. 54, pl. 9, figs. 5a–f, pl. 10, figs. 2a–c.

?Nesidea indica DOEGLAS, 1931, Wetenschap. Meded. No. 17, p. 35,36, pl. 4, figs. 2a–c.
Bairdia amygdaloides VAN DEN BOLD, 1957, Micropaleontology, v. 3, no. 3, p. 236, pl. 1, fig. 6a,b (*et syn.*).

A broken right valve referable to this species occurs in our material. It is a cosmopolitan species. Jacob & Sastri (1953) recorded it from the Miocene (Burdigalian) of Chavara, near Quilon, Travancore. Hornibrook (1952) recorded it from the Tertiary of New Zealand. *Nesidea indica* Doeglas from the Tertiary of N.E. Borneo appears to be identical with the present species.

This species is tentatively classed as *B. amygdaloides* Brady, though it appears to belong to the large group of *B. subdeltoidea* (von Münster), about which there is considerable difference of opinion concerning the taxonomy and distribution.

Family CYPRIDIDAE Baird, 1850
Subfamily CYPRIDINAE Müller, 1894
Genus PARACYPRIS Sars, 1866
PARACYPRIS sp. indet.
Pl. 41, fig. 2

A single indeterminate specimen belonging to this genus was found. More specimens are required to place this specifically.

Family CYTHERIDAE Baird, 1850
Subfamily CYTHERURINAE Müller, 1894
Genus PARACYTHERIDEA Müller, 1894
PARACYTHERIDEA sp. indet.
Pl. 41, fig. 3a,b

Only a right valve was found which, however, is too fragmentary to be identified specifically. The surface, particularly near the dorsal margin, is covered by irregular ridges.

Genus CYTHERURA Sars, 1866
CYTHERURA sp. indet.
Pl. 41, fig. 4

This again is an indeterminate species, being represented by a single left valve. The surface ornamentation consists of two irregular, zig-zag ridges, disposed longitudinally, with a small transverse ridge from the ventral one.

Subfamily TRACHYLEBERINAE Sylvester-Bradley, 1948
Genus ACTINOCYTHEREIS Puri, 1953
ACTINOCYTHEREIS LEVINSONI Bhatia & Mandwal, n. sp.
Pl. 41, fig. 5a,b

Diagnosis.—Carapace subquadrate, elongate-oval, slightly tapering towards the posterior end; both the cardinal angles protrude, antero-dorsal angle with a distinct eye-tubercle; dorsal margin straight, broken into a jagged-profile due to upward-pointing tubercles; ventral margin convex, fringed with about eight flattened, coalesced, spines, continuing along the postero-ventral margin; both anterior and posterior ends rounded, denticulate, the anterior with a well-marked marginal rim; surface ornamented with three horizontal, somewhat indistinct rows of tubercles; the antero-ventral area with a pronounced, large node; marginal area, hinge and muscle-scar pattern as for the genus.

Dimensions.—The holotype (Pl. 41, fig. 5a,b) measures 0.74 mm. in length; 0.38 mm. in height; 0.2 mm. in ½ width.

Discussion.—The present species is closely related to *Actinocytheris exanthemata* (Ulrich & Bassler), but differs from it in possessing a large, pronounced node in the antero-ventral area and more coalesced spines on the ventral margin. These differences are fairly constant (Levinson, personal communication).

Remarks.—The species is named in honor of Dr. Stuart A. Levinson, Humble Oil & Refining Company, Houston, Texas, for his many helpful comments and suggestions.

Genus BRADLEYA Hornibrook, 1952
?BRADLEYA sp. indet.
Pl. 41, fig. 6

A few diminuitive, complete carapaces, which may be questionably referred to this genus, occur in our material. The carapace is subrhomboidal, with a slightly attenuated posterior margin. The surface is covered with sinuous interconnected ridges, the eye tubercle being connected to the dorso-lateral rib. There is a prominent flange-like

projection on the ventro-lateral margin. Some of these characters are similar to those of *Bradleya clifdensis* Hornibrook. Our specimens, however, are decidedly smaller (maximum length being 0.43 mm.) than *B. clifdensis*.

Genus HERMANITES Puri, 1955
HERMANITES aff. H. HAIDINGERI (Reuss)
Pl. 41, fig. 7a,b

This species may questionably be referred to *H. haidingeri* Reuss (1850, p. 78, pl. 10, fig. 13) from which it differs in lacking the regular ornamentation and the anterior and posterior peripheral spines. Only a single, complete carapace was found. More specimens are required for specific identification.

Subfamily HEMICYTHERINAE Puri, 1953
Genus AURILLA Pokorny, 1955
AURILLA CICATRICOSA (Reuss)
Pl. 41, fig. 8

Cypridina cicatricosa REUSS, 1850, Naturwiss. Abh. herausgegeben V. Haidinger, v. 3, pt. 3, p. 67, pl. 9, fig. 21.
Cythere cicatricosa BOSQUET (*pars*), 1852, Mém. Cour. Acad. Roy. Belg., v. 24, p. 76, pl. 3, fig. 13.
Aurilla cicatricosa KEIJ, 1957, Inst. Roy. Sci. Nat. Belg., Mém. 136, p. 114, pl. 13, fig. 3; pl. 20, fig. 8.

Typical specimens of the species (identical with those from the Miocene of the Vienna Basin) occur in our material. The species has been reported from the Pliocene of Belgium and France; the Miocene of the Vienna Basin; Eocene and Oligocene of Belgium. This is by far the most abundant species in our material and a large number of detached valves and complete carapaces were found. No evidence of sexual dimorphism, however, was noticed.

Subfamily LOXOCONCHINAE Sars, 1925
Genus LOXOCONCHA Sars, 1866
LOXOCONCHA PUNCTATELLA (Reuss)
Pl. 41, fig. 9

Cypridina punctatella REUSS, 1850, Naturwiss, Abh. herausgegeben V. Haidinger, v. 3, pt. 3, p. 65, pl. 9, fig. 15.
Cythere punctatella BOSQUET, 1852, Mém. cour. Acad. Roy. Belg., v. 24, p. 75, pl. 3, fig. 12.
Loxoconcha punctatella KEIJ, 1955, Verh. Kon. Ned. Akad. Wet., ser. 1, v. 21, no. 2, pt. 4, p. 132, pl. 20, fig. 7,8; ——, 1957, Inst. Roy. Sci. Nat. Belg., Mém. 136, p. 143, pl. 22, figs. 12,13.

We have fairly typical specimens of the species in our material. In order of abundance, it is next to *Aurilla cicatricosa*. Only the valves of the female were found. This is a widely distributed species and ranges from Aquitanian to Helvetian.

Subfamily CYTHERINAE Dana, 1853
Genus CYTHEROMORPHA Hirschmann, 1909
?CYTHEROMORPHA sp. indet.
Pl. 41, fig. 10

Only a complete carapace was found, which may questionably be referred to the genus *Cytheromorpha*. The carapace is rhomboidal, highly inflated, with a prominent marginal rim and eye tubercle at the anterior end. The postero-ventral margin curves upwards. The left valve distinctly overlaps the right one at the anterior cardinal angle.

Subfamily CYTHERIDEIDINAE Puri, 1952
Genus KRITHE Brady, Crosskey and Robertson, 1874
KRITHE PAPILLOSA (Bosquet)
Pl. 41, fig. 11

Cytheridea papillosa BOSQUET (*pars*), 1852, Mém. cour. Acad. Roy. Belg., v. 24, p. 42, pl. 2, fig. 3.
Krithe papillosa KEIJ, 1953, Verh. Kon. Ned. Akad. Wet., ser. 1, v. 21, no. 2, pt. 4, p. 115, pl. 17, figs. 11–13; ——, 1957, Inst. Roy. Sci. Nat. Belg., Mém. 136, p. 85, pl. 8, figs. 1–4.

One right valve occurs in our material, but it is typical of the species. It is a well known species and ranges from Eocene to Miocene; the types were from the lower Miocene.

Suborder PLATYCOPA Sars, 1866
Family CYTHERELLIDAE Sars, 1866
Genus CYTHERELLA Jones, 1844
CYTHERELLA COMPRESSA (von Münster)
Pl. 41, fig. 12

Cythere compressa VON MÜNSTER, 1830, Jahrbuch f. Mineralogie usw., p. 64.
Cytherella compressa KEIJ, 1957, Inst. Roy. Sci. Nat. Belg., Mém. 136, p. 45, pl. 1, fig. 10. (*et syn.*).

One complete carapace was found. The species is known to range from Eocene to Miocene.

Genus CYTHERELLOIDEA Alexander, 1929

?CYTHERELLOIDEA sp. indet.

Pl. 41, fig. 13

Only one carapace was found which could not be specifically determined.

CYTHERELLOIDEA aff. C. CINGULATA (Brady)

Pl. 41, fig. 14a,b

Cytherella cingulata BRADY, 1868, Les Fonds de la Mer, v. 1, p. 159, pl. 16, figs. 24,25; ——, 1880, Rept. Voy. Challenger, Zool., v. 1, p. 177, pl. 43, figs. 1a–g; figs. 2a–d.

We have only a complete carapace in our material, belonging to this characteristic Indo-Pacific species. It has not previously been reported in the fossil state. Although this species is similar to *C. cingulata* described and figured in the Challenger report, it differs from the form described by Brady in 1868 in that the Fonds de la Mer species lacks the connection of the horse-shoe ridge at the posterior.

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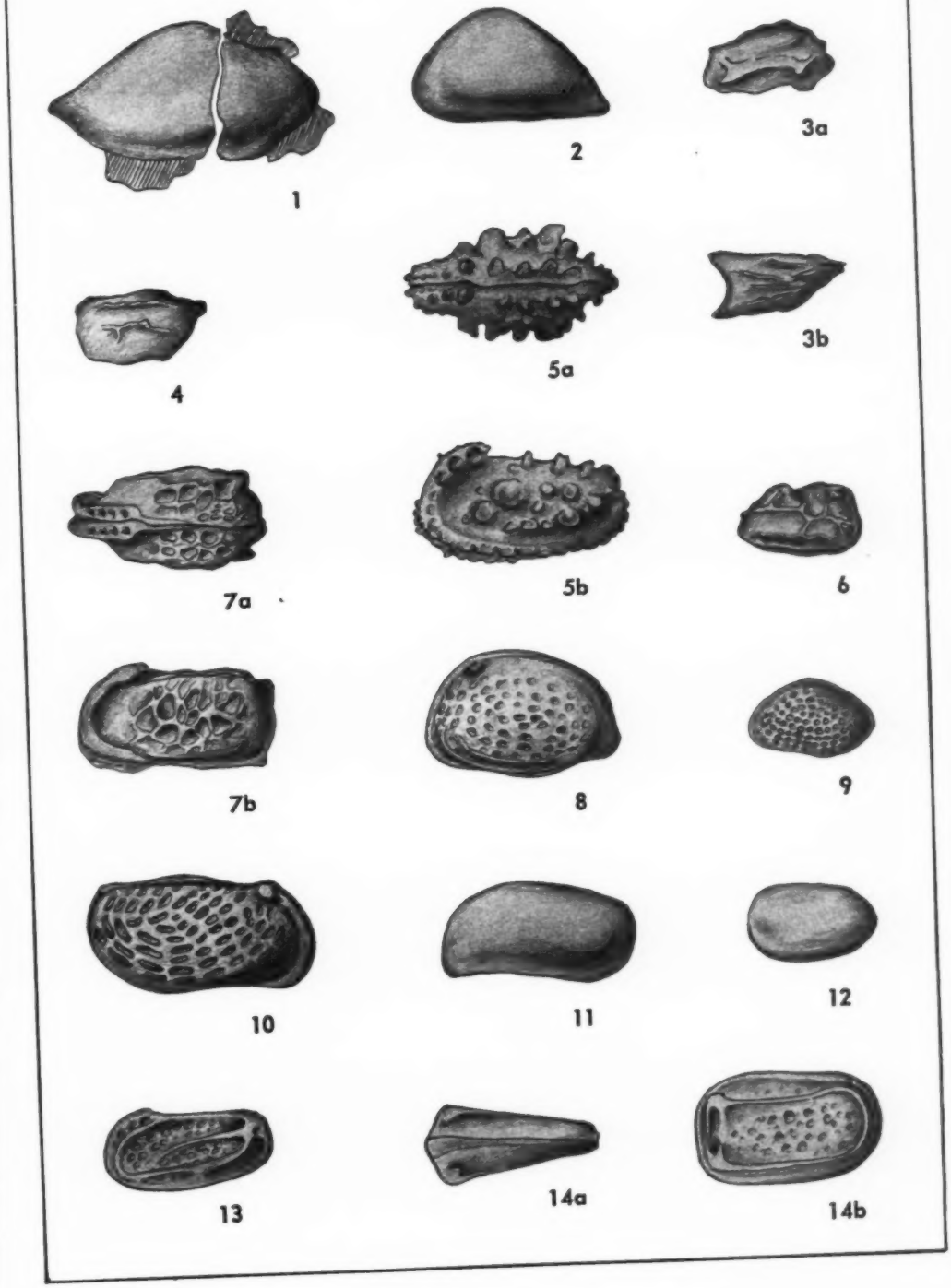
(*Explanation of* PLATE 41 *on next page.*)

EXPLANATION OF PLATE 41

All figures ×42

FIG. *1*—*Bairdia amygdaloides* Brady. Right valve, lateral view.
2—*Paracypris* sp. indet. Left valve view of a complete carapace.
3—*Paracytheridea* sp. indet. *a*, Lateral view; *b*, dorsal view of the right valve.
4—*Cytherura* sp. indet. Left valve, lateral view.
5—*Actinocythereis levinsoni*, n. sp., holotype. *a*, dorsal view; *b*, left valve view of the complete carapace.
6—*?Bradleya* sp. indet. Right valve view of a complete carapace.
7—*Hermanites* aff. *H. haidingeri* (Reuss). *a*, dorsal view; *b*, left valve view of a complete carapace.
8—*Aurilla cicatricosa* (Reuss). Left valve, lateral view.
9—*Loxoconcha punctatella* (Reuss). Right valve view of a complete carapace.
10—*?Cytheromorpha* sp. indet. Right valve view of a complete carapace.
11—*Krithe papillosa* (Bosquet). Right valve, lateral view.
12—*Cytherella compressa* (von Münster). Left valve view of a complete carapace.
13—*?Cytherelloidea* sp. indet. Left valve view of a complete carapace.
14—*Cytherelloidea* aff. *C. cingulata* (Brady). *a*, dorsal view; *b*, right valve view of a complete carapace.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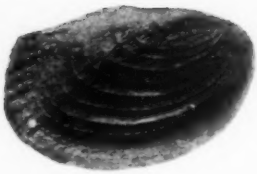

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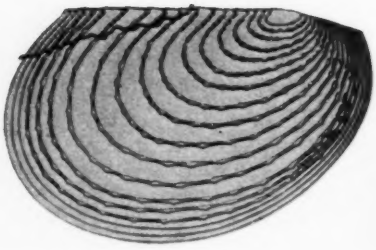

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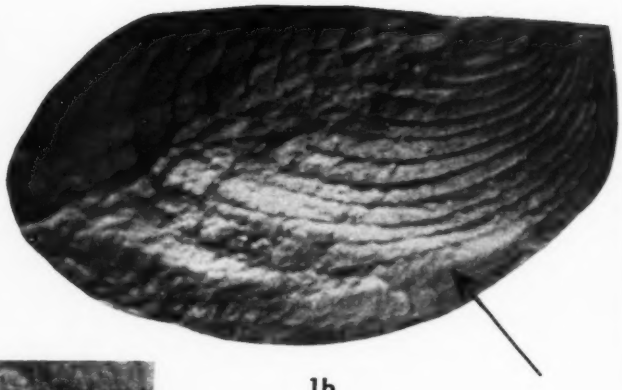

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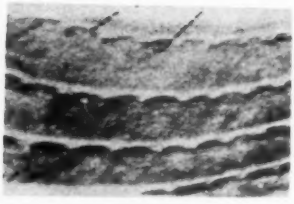

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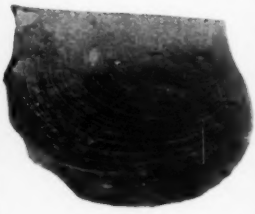

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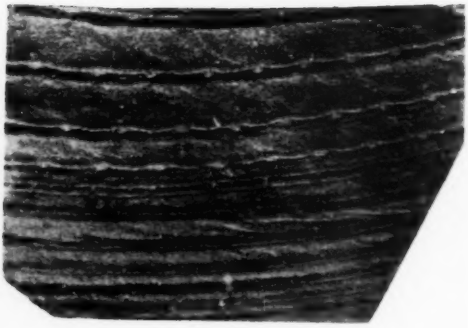

4b

JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 285–289, PL. 42, MARCH, 1960

CONCHOSTRACAN GENUS *ANOMALONEMA* IN THE AMERICAN PENNSYLVANIAN

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ABSTRACT—A new conchostracan species, *Anomalonema* (*Pierrepruvostia*) *williamsii* is described from the shale above the Upper Kittanning coal, Clearfield County, Pennsylvania. This is the first representative of the genus found outside the coal fields of Northern France. Novojilov's new genus, *Pierrepruvostia*, is reduced to subgeneric status, and his subfamily Anomalonematinae is rejected. Two new subgenera of the genus *Anomalonema* are proposed: *Pierrepruvostia* and *Anomalonema*, the former lacks postero-dorsal recurvature and has a non-terminal beak, the latter has postero-dorsal recurvature and a terminal beak; both subgenera share the generic character of tubercles (interrupted radial lirae) margining growth lines. This feature gives a scalloped appearance to growth line peripheries. Raymond's questionable assignment of Chernyshev's specimens to the *Anomalonema* is rejected, and these specimens are assigned to the *Estheriella*. The inferred relationship between Pruvost's "tubercles" and "indentations" on the new species is supported by measurements of distance between any two adjacent pairs of each. Almost complete agreement was found between these sets of figures. Comparison with measurements on valves of the living species *Caenestheriella belfragei* establishes the fact that distances between any two adjacent spines or setae bases is a hundredfold less than between any two tubercles or indentations. These data indicate that the latter features are "interrupted radial lirae" and could not have been spines or setae bases in the living animal.

INTRODUCTION

DURING the course of a biofacies study of the Upper Allegheny rocks in Western Pennsylvania, E. G. Williams of Pennsylvania State University collected some conchostracan fossils. Among his collections were several leaiid and estheriid types. A single external cast of a specimen, not found in association with the other conchostracans mentioned, was tentatively assigned by Williams to *Anomalonema reumauxi*. This specimen, which I have on

EXPLANATION OF PLATE 42

FIG. *1a–c*—*Anomalonema* (*Pierrepruvostia*) *williamsii*, n. sp., *1a*, external cast of right valve (holotype); on the shale slab the specimen is oriented in a reverse position to that shown in photographs *1a–c;* the beak occurs at the left and, as would be expected for a right valve that had been crushed down into clay mud, convexity is downward; note indentations peripheral to growth lines (*cf.* figs. *4a,b*) (corrected photograph after Williams), ×12; *1b*, heavy magnesium powder coating and median illumination were used to bring out scalloped effect of indentations (see arrow), *cf. 4a*, ×14; *1c*, faint magnesium powder coating was used to bring out indentation pattern in the median sector (see arrow); note non-terminal beak position and absence of postero-dorsal recurvature, ×11 (figs. *1a–c* are all taken from the same specimen.

2a,b—*Estheriella reumauxi* Pruvost (1919, pl. 24, fig. 34), *2a*, note general configuration and postero-dorsal missing sector, ×8; *2b*, *Pierrepruvostia defretinae* Novojilov, 1958 [(=*Anomalonema* (*Pierrepruvostia*) *defretinae* Nov. Tasch, 1959)]; note the degree of interpretation involved in this figure compared with the original photograph, fig. *2a:* in the antero-dorsal margin that is rounded in fig. *2a;* in the character of the scalloped effect which appears different from that in fig. *4a* with which it should be identical; in the missing portion depicted as if a fracture occurred at that place (see arrow), ×8; *2c*, Novojilov's imaginative restoration of the details of ornamentation with the only evidence to go on being figs. *2a* and *4b* (Novojilov, 1958, fig. 7a, p. 14), ×100.

3—*Estheriella reumauxi* Pruvost (1919, pl. 24, fig. 35) [=*Anomalonema reumauxi* (Pruvost) Raymond 1946], note the postero-dorsal recurvature and terminal beak position, ×5.

4a,b—Details of anomalonemiid ornamentation. *4a*, Pruvost's "tubercles"; the "indentations" seen in figs. *1a–1c* are impressions of such tubercles (see text, this paper, for measurements) (Pruvost, 1911, pl. 1, fig. 16), ×9; *4b*, the same (Pruvost, 1919, pl. 24, fig. 35a), ×35.

loan, was found to belong to a new species.

Since no representative of the genus has ever been reported outside of the coal fields of Northern France (roof of the Arago vein at Lens and Liévin, Upper Westphalian), this important find supplements our knowledge of the genus and its distribution.

ACKNOWLEDGEMENTS

I am indebted to E. G. Williams for loan of the specimen described herein and for making available other Pennsylvanian conchostracans in his collection. Illustrations for this paper and translations of Novojilov's papers into French were made possible by a Sigma Xi grant-in-aid.

PRUVOST, RAYMOND, NOVOJILOV

It is impossible to discuss the taxonomy of any fossil conchostracan without first spelling out, in some detail, the status of the classification as it has evolved from one worker to another.

Pruvost (1911, 1919) thought *A. reumauxi* was closest to, though admittedly different from, *Estheriella costata* Weiss. He was led to this conclusion by his observation that in *Estheriella* the radial sides are resolved into tubercles. In his own specimen he was impressed mainly by the illusion of radial lines crossing the concentric sides. He showed that these were produced by small tubercles. The tubercles, in turn, were resolved into two parts, the tubercle side and striae which accompany it (Pl. 42, fig. 4a). In addition, the specimen was limnadiform, i.e., showed recurvature at the postero-dorsal margin.

Raymond (1946, p. 274,275 and text-fig. 3), in the course of a wholesale reassignment of conchostracan genera, based primarily on published accounts, assigned Pruvost's species to a new genus, *Anomalonema*. The recurved growth lines at the postero-dorsal margin immediately led him to place it in the Limnadiidae which have valves showing a similar character. With a degree of uncertainty, he also assigned Chernyshev's *Estheriella* species to the new genus.

The illustrations in Chernyshev's paper (1926, pl. 7) are very poor. Studied under magnification, the absence of a postero-dorsal recurvature can be seen while the presence of Pruvost's tubercles cannot. In place of tubercles, one finds estheriellid-type lirae which do not appear to be discontinuous as in *Anomalonema*. Hence, these specimens are more properly assignable to *Estheriella*.

TWO NEW SUBGENERA OF *ANOMALONEMA*

In 1958 (Novojilov, 1958), Novojilov established a new subfamily Anomalonematinae. This was based solely on published accounts by Pruvost and Raymond. It was to embrace the genera *Anomalonema* Raymond and *Pierrepruvostia* Novojilov, n. gen. It is the new genus that must concern us here. It is based on one of Pruvost's specimens (1919, pl. 24, fig. 34, *non* 35) of *A. reumauxi* (Pl. 42, fig. 2a).

From study of Pruvost's 1919 paper, several things become clear. Figure 34 of that paper shows a specimen eroded at the dorsal and postero-dorsal margin, and possibly peripherally at the ventral margin. Novojilov's line drawings (Pl. 42, figs. 2b,c) do not correspond in detail with Pruvost's photographs. For example, Novojilov's drawing shows a break as if a fracture appeared in the specimen and also shows the restored portion of the valve including the postero-dorsal margin which is missing. However, the restored portion of the valve is an imaginative restoration and should have been dashed-in to show it is actually missing by erosion (*cf.* Pruvost, 1911, fig. 1a for a correct representation of a missing portion of a fossil).

Although Pruvost (1919, fig. 35a) shows a $\times 35$ enlargement of the peripheral ornamentation of growth lines, this photograph, when studied under magnification, shows no definable details of ornamentation between growth lines (Pl. 42, figs. 4a,b). However, Novojilov gives a $\times 100$ enlargement of Pruvost's figure 35a (Pl. 42, fig. 2c) and provides remarkable details that cannot be seen in the original photograph.

The way Novojilov's drawing (Pl. 42, fig. 2b) shows the peculiar *Anomalonema*-type ornamentation, it would appear to be different from that of *Anomalonema reumauxi*. This, too, cannot be derived from the original photograph (Pl. 42, fig. 2a). Nor was it observed by Pruvost in his 1911 or 1919 papers.

We are thus left with the following verifi-

able evidence: the probably ovate shape of the valve; the probable absence of posterodorsal curvature; and the unquestioned position of the beak (i.e., it is not anteroterminal, but located inward from the anterior margin). It is in light of these data that we must evaluate the new subgenus *Pierrepruvostia* since it is based on *P. defretinae* (= Pruvost, 1919, pl. 24, fig. 34).

I am persuaded by careful study of the published evidence and bolstered by study of the new material at hand and described herein, that two subgenera of *Anomalonema* should be erected. The purpose of this step is to distinguish between anomalonemiid specimens which share the characteristic ornamentation yet differ in beak-position and other characteristics.

The following subgenera are therefore proposed: *Anomalonema* subgenus *Anomalonema* of which the type is *Estheriella reumauxi* Pruvost (1911, pl. 1, figs. 1–3). This subgenus is characterized by forms having a recurved posterodorsal margin and a terminal beak. The second subgenus will retain the name proposed by Novojilov, *Pierrepruvostia*, but reduces it from its original generic status. Thus, *Anomalonema*, subgenus *Pierrepruvostia*. The "indication" for this subgenus type will not be the imaginative drawing presented by Novojilov and called *Pierrepruvostia defretinae* nor will it be based on the features he described. Rather, it is based on Pruvost's 1919 paper (pl. 24, fig. 34). It characterizes anomalonemiids that actually or apparently lack posterodorsal recurvature and have a beak that is non-terminal in position.

FURTHER TAXONOMIC CONSIDERATIONS

It has already been observed that Raymond thought that the recurved posterodorsal margin of *A. reumauxi* made it a representative of the Limnadiidae. However, Tasch (1956, table 1) agreed with Kobayashi that it belonged to the family Estheriellidae. This was based on several considerations: Pruvost's original designation of his material as estheriellids (1911, 1919); the non-crossing of the umbo by radials (Tasch, *op. cit.*, p. 1255), and the apparent similarity of *Anomalonema*-type "interrupted radial lirae" to the "continuous" radial liration characteristic of the estheriellids. Study of the new species described in this paper strengthens this conclusion.

This assignment contrasts strikingly with Novojilov's questionable assignment of his proposed new subfamily (that is rejected in this paper) Anomalonematinae to the family (?) Lioestheriidae. Elsewhere, Tasch (1956, p. 1253,1254) discusses this last named family. It will suffice to indicate here that rejection of the subfamily proposed by Novojilov leaves the genus *Anomalonema* with the estheriellid-type conchostracans. Three students of this fossil group, Pruvost, Kobayashi, and the present writer, independently reached this conclusion.

Another point to be clarified pertains to Novojilov's erecting *Pierrepruvostia* as a new genus based on the following comparison: "Le genre *Pierrepruvostia* se distingue du genre *Anomalonema* par les valves-obliques." As discussed elsewhere (Tasch, 1958), valve shape is hardly suitable as the chief criterion for establishing higher categories of fossil conchostracans. This qualification becomes even more restrictive in light of the incomplete valve figured by Pruvost (1919, fig. 34) and discussed above.

From the point of view of an effective taxonomy (Tasch, 1956, p. 1254), one can instantly classify *Anomalonema*-related species on the basis of a single characteristic, "interrupted radial lirae." The same recognition cannot be achieved by any other character or set of characters. Since that is a matter of fact, all other characters should be regarded as subordinate. Setting up two subgenera achieves this precise result. It does so without proliferating higher categories, an end which, in the present state of fossil conchostracan taxonomy, seems especially desirable.

RELATIONSHIP OF TUBERCLES IN FOSSIL FORMS TO SIMILAR STRUCTURES IN LIVING CONCHOSTRACANS

Study of the indentations on the new species described in this paper caused me to wonder if they might be related to either spines or setae bases found in some living forms. That led me to compare my observations and measurements on the living species *Caenestheriella belfragei* with the fossil material. While the details of these observa-

tions, which will be published elsewhere, are not all relevant here, those pertaining to spines margining growth lines and to setae bases are.

The distance between any two adjacent spines was found to range between .003–.006 mm. measured between a median line through each spine. A figure of .002–.006 mm. was the distance found between any two adjacent setae bases.

Between any two adjacent tubercles on Pruvost's enlarged photograph (×35) (1911, pl. 1, fig. 1b) the distance was found to be .14 mm.–.17 mm., while for the indentations on the new species described in this paper, the distance was found to be .11 mm.–.17 mm. It is thus apparent that the almost complete agreement in these figures supports the inferred relationship between "tubercles" and "indentations." Furthermore, it is reasonable to conclude that the sets of figures for both spines and setae bases given above are of a different magnitude. While variations in such figures can be expected in different genera and species, it would be unreasonable to expect any greater than a tenfold increase in the distance between any two adjacent spines or setae bases due to this cause. What is found in the living forms studied is a hundredfold greater proximity of any two adjacent spines or setae bases than for any two tubercles or indentations in fossil anomalonemiid valves.

We may therefore exclude "tubercles" as sites of spines or setae bases in the living animal now represented by fossil valves. The other possibility is that they are "interrupted radial lirae" as Raymond designated them. Continuous lirae appear to have served as a strengthening structure in the valve as in the Estheriellidae (Tasch, 1956). Discontinuous lirae may have become a relict structural element of the valve through mutations of an estheriellid-type.

SYSTEMATIC DESCRIPTION

Family ESTHERIELLIDAE Kobayashi, 1953

Genus ANOMALONEMA Raymond, 1946

Subgenus PIERREPRUVOSTIA Novojilov, 1958 (Tasch 1959)

ANOMALONEMA (PIERREPRUVOSTIA) WILLIAMSII Tasch, n. sp.

Pl. 42, figs. 1a–c

Diagnosis.—Elongate, subelliptical; no recurvature of growth lines at posterodorsal margin; dorsal margin straight; midpoint of beak situated slightly more than two times as far from the posterior margin as from the anterior; apex of beak missing by erosion.

Growth lines number 18 to 20; periphery of each visible growth line bears closely-spaced, minute hollow indentations that give the illusion of what Raymond called "interrupted radial lirae." These indentations correspond to Pruvost's "tubercles" (Pl. 42, figs. 1b,4a,b) and are the impression of such ornamentation. They also give a faintly defined scalloped appearance to growth line peripheries. The indentations are broader at the base in contact with any given growth line that they rim, and tend to be pointed posteriorly.

The single external cast of a right valve that is at hand is crushed, as can be seen by the diagonal bruise (Pl. 42, figs. 1a–c). The growth lines on either side of this bruise are not offset.

TABLE 1—DIMENSIONS OF SPECIES OF *ANOMALONEMA*

Species	Max. Length	Max. Height	Cardinal Line
Anomalonema (*Anomalonema*) *reumauxi* (Data from Pruvost, 1919)	5.0–6.0 mm.	3.5–4.5 mm.	3.5–5.0 mm.
Anomalonema (*Pierrepruvostia*) *williamsii* (Data from holotype)	6.00	3.15	4.65
Anomalonema (*Pierrepruvostia*) *defretinae* (Data from Pruvost, 1919, pl. 24, fig. 34)	5.8	3.8	indeterminable

Discussion.—The only other specimen assignable to *A.* (*Pierrepruvostia*) is A. (*P.*) *defretinae.* Since it has been indicated that Novojilov's depiction of Pruvost's specimen is misleading, reference will be made to the original photograph (Pruvost, 1919, pl. 24, fig. 34).

The new species differs from *A.* (*P.*) *defretinae* in several characteristics: the dorsal margin is straight throughout its entire extent, in contrast to Novojilov's species; the dorsal anterior sector is slightly oblique in a manner closer to *A.* (*A.*) *reumauxi* than to Novojilov's species, which is rounded in this sector (*cf.* Novojilov's fig. 2b that distorts this feature). The new species has a more subdued scalloped effect due to peripheral indentations ("tubercles") than Novojilov's species. Pruvost, it should be noted, did not figure a separate enlargement of both his figures, that is, figure 34 and figure 35 (Pl. 42, figs. 2a,3) and thus only figure 35 applies to Novojilov's new species (based on Pruvost, 1919, fig. 34) as well.

Lastly, the new species is subelliptical, while Novojilov's species is subovate. This is seen when one compares the dimensions for height and length in Table 1. It will be seen that Novojilov's species is measurably higher than the new species and also detectably shorter in length. These figures clarify the actual difference in overall valve configuration. In itself I would not regard such a difference as being of specific value in the present instance. However, in association with the straight dorsal margin, obliquity of antero-dorsal margin and discernible, although minor, ornamental variation, a new species is indicated.

Locality.—Silty shale above Upper Kittanning coal (44 feet above Coal C′) five miles east of Clearfield, Clearfield County, Pennsylvania (data by Williams).

Repository of holotype.—Pennsylvania State University, School of Mineral Industries.

Age.—Pennsylvanian, Alleghenian, equivalent to the Upper Westphalian of Europe.

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JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 290–346, PLS. 43–50, 3 TEXT-FIGS., MARCH, 1960

UPPER CRETACEOUS FORAMINIFERA FROM NEAR REDDING, SHASTA COUNTY, CALIFORNIA

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ABSTRACT—Three Late Cretaceous shale units cropping out in the northern Great Valley have been sampled for foraminiferal content. Approximately 2500 feet of section is represented in association with 1500 feet of sandstone. Ninety species of Foraminifera—twenty-two of which are new—are illustrated, described and their stratigraphic ranges determined. One new name is proposed. Two distinctive faunas are recognizable, the division coinciding approximately with the Turonian-Senonian boundary. Arenaceous species constitute the greater number of individuals; while for stratigraphic purposes the Orbulinidae—especially the genus *Globotruncana*—are dominant in the Turonian and they, with the Rotaliidae, are of greatest importance in the Senonian. Most of the species have been previously reported from the European and Gulf Coastal regions. An interpretation of the paleoecology indicates a sublittoral zone as the site of deposition for associated sediments. On the basis of foraminifers and diagnostic megafossils, the ages of the units are determined as Middle Turonian, Coniacian, and Santonian.

INTRODUCTION

UPPER Cretaceous foraminiferal assemblages of California and the Pacific Coast area in general have received little attention in published literature. Only brief mention has been made of Foraminifera from the Sacramento Valley. This neglect stems largely from the lack of interest by the petroleum industry although important discoveries made in recent years, notably of natural gas, have caused some activity in the northern California and Oregon area.

The area of study is located about 10 miles east of the city of Redding, Shasta County, California (Text-fig. 1). The three general localities from which samples were collected are within the bounds of the 15 minute Millville Quadrangle. Each of the three general localities includes a shale section herein referred to as Members II, IV, and VI, as given by Popenoe (1943). The geological relationship of these members in the section as well as the sample localities is shown in Text-figure 2.

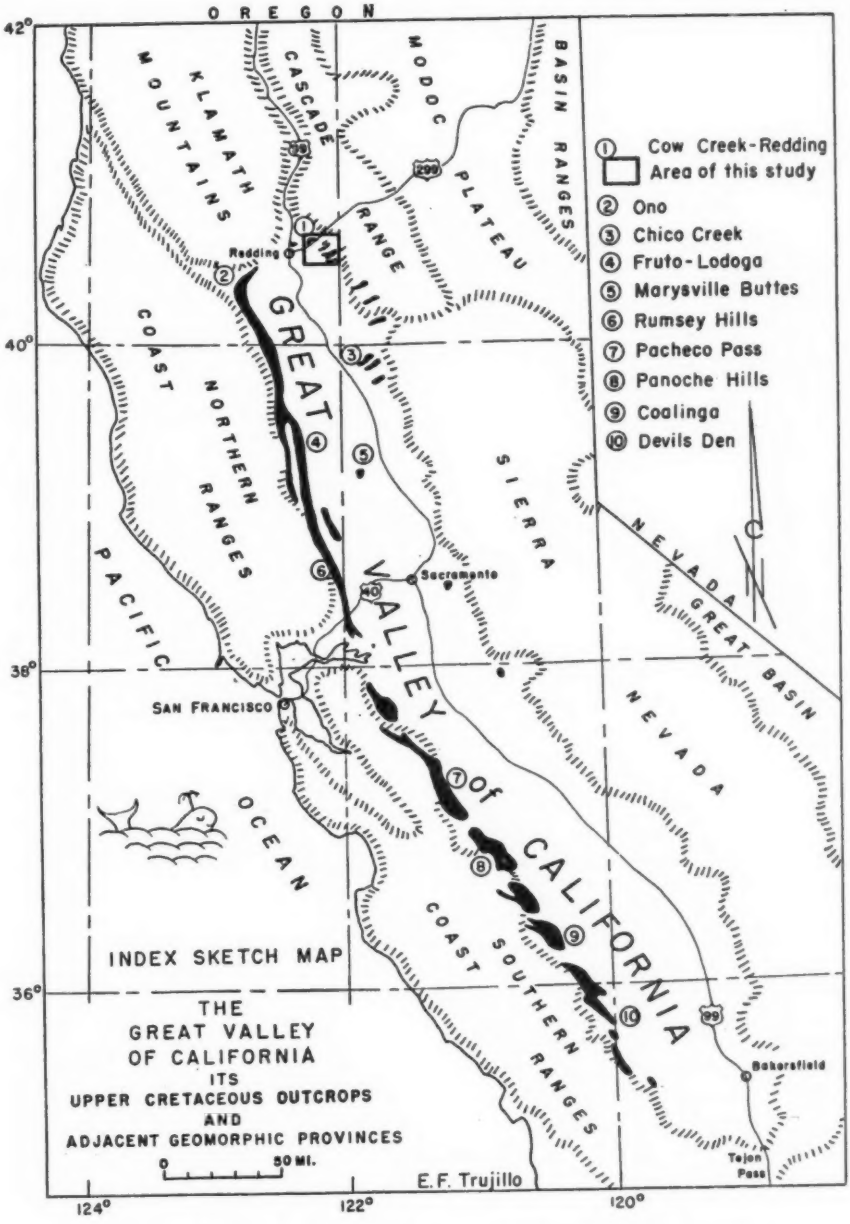
Original plans called for sampling each member at known stratigraphic intervals, but poor exposures and structural complications made this impossible. The sample localities are in correct stratigraphic sequence as nearly as could be ascertained; however, the stratigraphic interval between localities was in general impossible to determine accurately. A total of 140 samples was examined, and 91 were used in the study. Of these, 22 are from Member II, 48 from Member IV, and 21 from Member VI. The number of samples from each member does not indicate a like ratio of stratigraphic thicknesses, but rather reflects the adequacy of exposures.

All illustrations were drawn by the author, using a Zeiss Drawing Apparatus to outline the characteristic features of the specimens.

ACKNOWLEDGMENTS

It is a sincere pleasure to acknowledge all assistance that has been given the writer during the course of the study.

J. C. Roth, of the University of California, Los Angeles, collected most of the samples on which the study was based and S. Trujillo of Los Angeles assisted in preparation of the samples. A. Marianos, of the Humble Oil Company, Chico, California helped with problems encountered in preliminary work. O. L. Bandy, of the University of Southern California, examined the complete fauna and offered helpful suggestions; H. M. Bolli, of Texaco Trinidad Inc., Point-a-Pierre, Trinidad, B.W.I., examined specimens belonging to the family Orbulinidae; T. Matsumoto, of Kyushu University, Japan, furnished information from his study of the ammonites in the Redding area. Ruth Todd compared specimens with type material in her care at the United States National Museum, Washington,



TEXT-FIG. *1*—Index map showing important Upper Cretaceous outcrops.

D. C. Others, from the University of California, Los Angeles, who have given considerable aid are: Opal Kurtz, Lou Ella Saul and Mary Wilson; P. C. Durham, A. Stoyanow and E. L. Winterer; J. Cox and T. Susuki. The use of the laboratories and other fine facilities of the University is duly acknowledged.

Helen Tappan Loeblich of the University of California, Los Angeles and the United States Geological Survey read the final manuscript and kindly offered suggestions relative to various systematic problems.

Finally, it is with extreme gratitude that I thank W. P. Popenoe of the University of California, Los Angeles for suggesting the problem, furnishing preliminary samples, and for aid and encouragement extended during the preparation of this paper.

HISTORICAL REVIEW

Although the presence of Cretaceous strata in the northern Great Valley was well known in the latter part of the nineteenth century, it was not until 1906 when Diller mapped the Redding quadrangle for the United States Geological Survey that the Upper Cretaceous outcrops in the tributary valleys of Cow Creek were first delineated. The sandstone and shale beds were not separately mapped but were included by Diller in one unit, the Chico Formation. Since the Chico Group was first introduced by William M. Gabb (1869, p. 129, footnote) the terms "Chico Group," "Chico Series" and "Chico Formation" have been used indiscriminately in referring to all rocks in California of Late Cretaceous age. This has resulted in considerable confusion which may be avoided by properly referring the strata to the Upper Cretaceous Series. The Chico Formation in the restricted sense at the type locality on Chico Creek is Upper Coniacian to Lower Campanian in age (Popenoe, oral communication). Following Diller's work, no further descriptions of the area were published until 1943, when Popenoe issued a progress report on his studies of the paleontology and stratigraphy. At that time he divided the Upper Cretaceous strata in the Redding district into six units, designated Members I–VI. In a future paper now in preparation he proposes (oral communication) to give formal names to the units and to describe the gastropod and pelecypod faunas. The ammonite fauna is to be described and analyzed in a publication by Dr. T. Matsumoto of Kyushu University, Japan. The recent posthumous publication of Anderson (1958) contains some discussion of the stratigraphy and age, and describes several large invertebrates from the Redding area.

To date, there has been no publication on the Foraminifera from the area of this study. The first description of a California Upper Cretaceous foraminiferal fauna was by Cushman & Church (1929) from the Coalinga area. In 1935 Cushman & Campbell reported on a fauna from well samples taken from the Moreno shale near Tracy. Cushman & Goudkoff (1944) described species from various horizons of the Upper Cretaceous of the San Joaquin Valley. A zonation of the California Upper Cretaceous by means of Foraminifera was presented by Goudkoff (1945), in which 16 divisions were established on the basis of outcrop and subsurface sampling throughout the Great Valley. Several species were described by Cushman & Todd (1948) from the New Almaden area. Bandy (1951) published the only paper on the southern California Upper Cretaceous foraminifers and was the first to include a complete fauna; the previous authors in general having included only selected species that were thought to be of greatest stratigraphic importance. Küpper published two short papers, one a restudy of the fauna of the New Almaden district (1955), and the other (1956) on the pelagic foraminifers from the "Antelope shale."

DESCRIPTIVE GEOLOGY

The stratigraphy of the area has been previously described in a general way by Diller (1906), and in a more detailed manner by Popenoe (1943). It will therefore be discussed only briefly here.

Topographically and structurally, the Sacramento Valley is an elongate northward-trending depression between the Sierra Nevada to the east and the northern Coast Ranges to the west, while the Cascade Range and Klamath Mountains are to the north. It forms, with the San Joaquin Valley to the south, the Great Valley of

California. The area under discussion lies in the northeastern part of this valley (Text-fig. 1).

Here, the Cretaceous rocks are warped into a broad, shallow syncline with a northeast-trending axis approximately coinciding with upper Clover Creek valley. The beds dip very gently, ordinarily less than 10 degrees, and in some places are essentially flat. They rest with a pronounced angular unconformity upon the Triassic Pit Formation. Overlying them are Cenozoic surface rocks of terrestrial sediments and the lavas, tuffs, ash beds and other rocks that are referred to the Tuscan Formation (Text-fig. 2). These surface rocks have been partly eroded away by the tributaries of Cow Creek so that the Cretaceous rocks are exposed in the stream valleys but not on the interstream divides (Popenoe, 1943, p. 307).

Exposures suitable for sampling are found only along parts of the stream channels and in some of the gullies; elsewhere there is a thick mantle of soil covered by heavy grass, and in some areas the land is under cultivation.

Inasmuch as the exposures are separated and in places considerably faulted, it is difficult to obtain exact thicknesses. The total thickness of the six members, however, is estimated to be about 4000 feet, The stratigraphic column (Text-fig. 3) shows the thicknesses of the individual units as given by Popenoe (1943). Members I, III, and V consist for the most part of massive arkosic sandstone and were not included in this study as foraminifers are extremely rare in the sandstone. A few random samples were examined, but with the expected negative results.

Member II consists of 800 feet of silty and sandy, commonly very micaceous shale with interbedded sandstone and some ironstone concretionary beds. The shale is dark gray and is in gradational contact with both the underlying and overlying members.

The shale of Member IV is lithologically quite similar to that of Member II except that it is darker colored and generally does not have a high mica content. The lower contact with Member III is not exposed in Clover Creek where the sampling was done, but elsewhere it appears to be conformable. There is a sharp lithologic break at the contact with the overlying Member V. In some places there is a variance in dip of several degrees, and in other places, notably on Clover Creek, the two members are in fault contact. The estimated thickness of 1000 feet for Member IV is highly questionable.

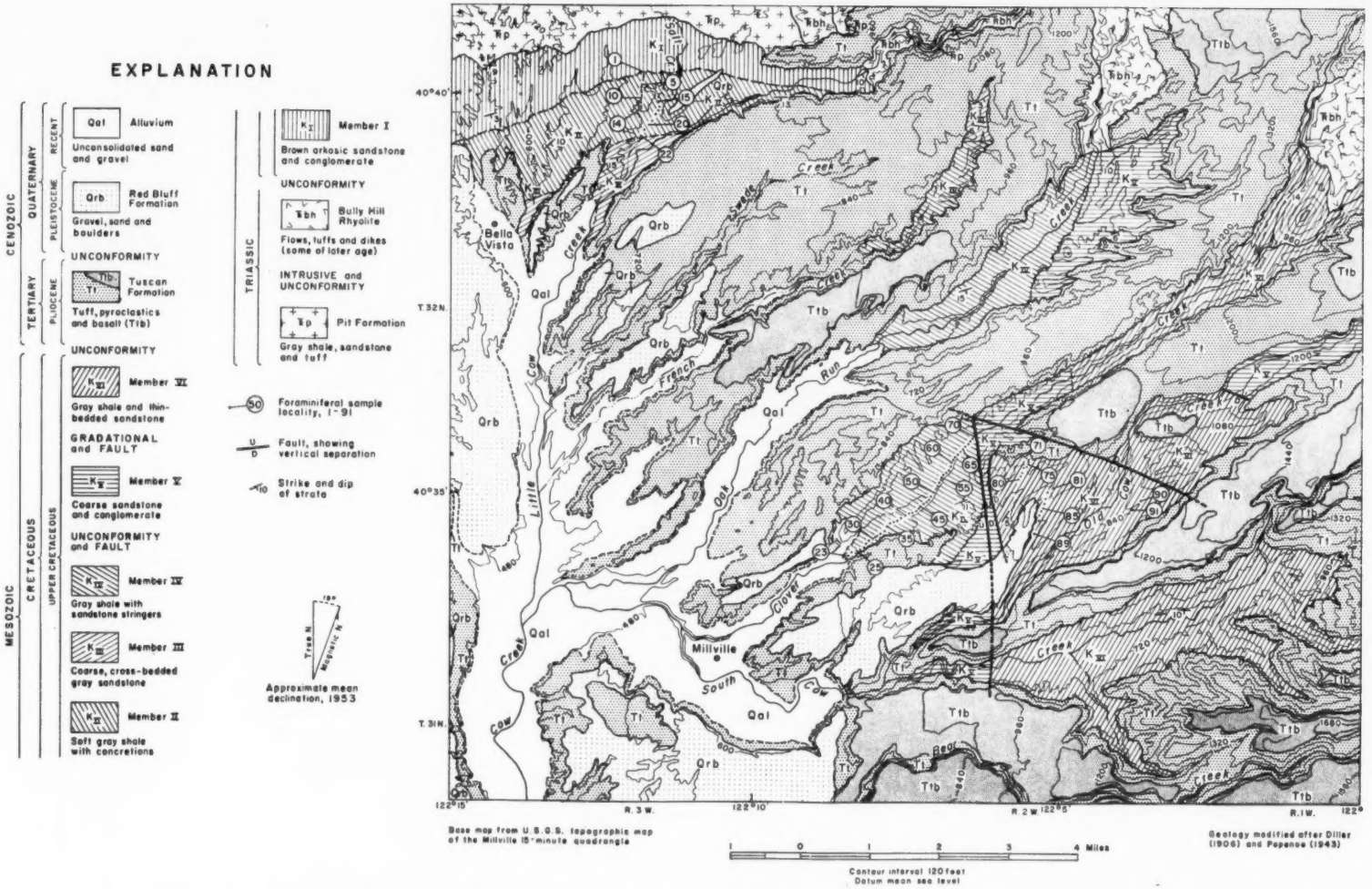
Member VI differs from the other two members principally in being better layered and containing more sandstone. It has an estimated approximate thickness of 1000 feet. The lower contact is in part gradational with Member V; however, in the Clover Creek region it is in fault contact with Member V. A very thin Tertiary sandstone bed that Diller referred to the Ione Formation unconformably overlies Member VI and the other Cretaceous outcrops in many places. There is no evidence for referring it to that formation, and for the purposes of this study it has been included in the Tuscan Formation.

Although the outcrops near Redding are some of the best developed of the few on the east side, they form but a small part of the total Upper Cretaceous in the Great Valley. Some of the better known sections are indicated on Text-figure 1, which also shows that most of the Upper Cretaceous exposures of the valley are on the west side, extending nearly the complete length.

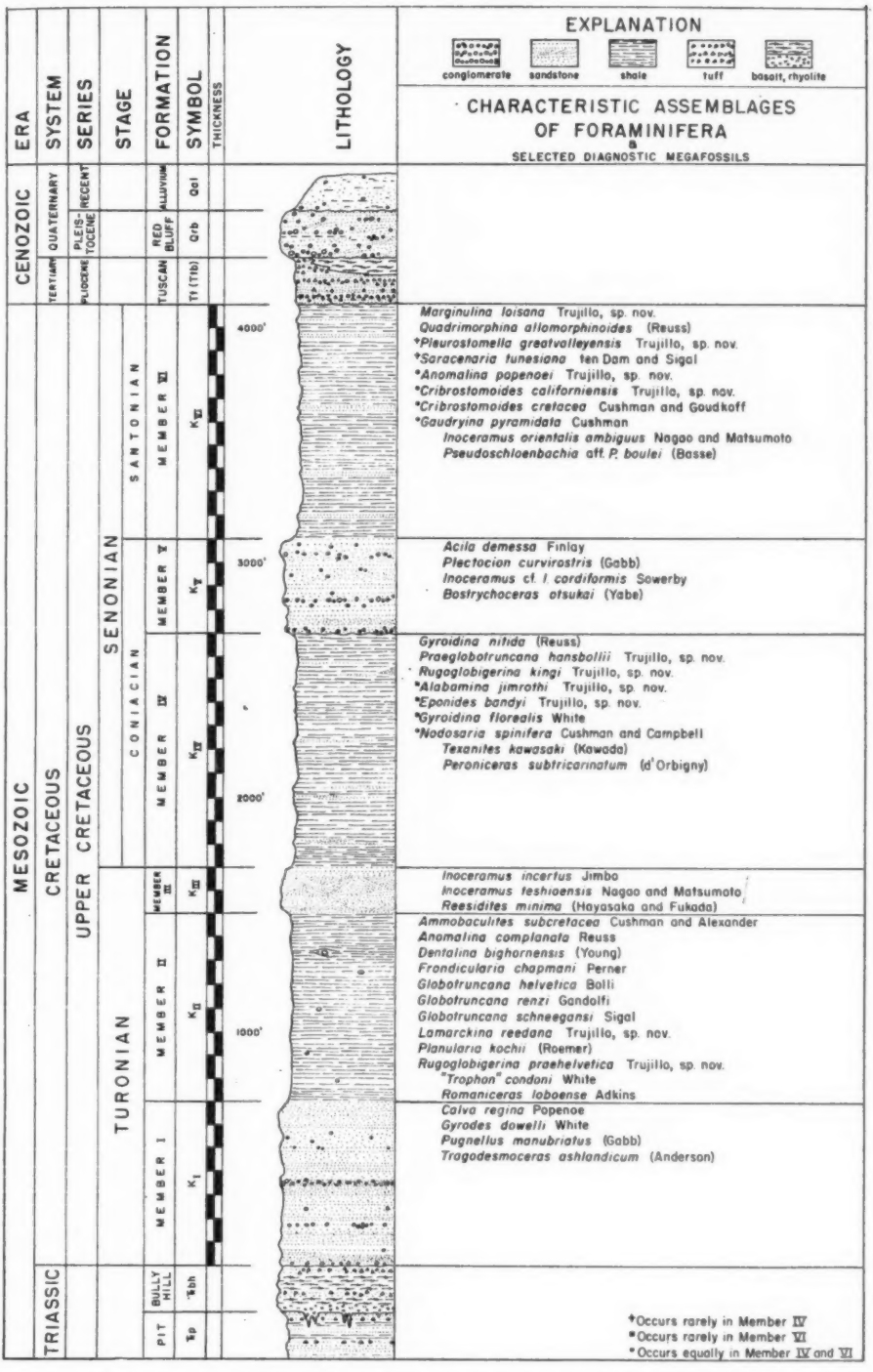
SAMPLE ANALYSIS

A preliminary analysis of samples indicated a marked paucity of Foraminifera per gram weight of sediment so large samples (500 grams) were used. Most of the samples were well indurated and did not respond to ordinary procedures for the disintegration of sedimentary rocks. The procedure used is as follows: (1) mix sample thoroughly, weigh out 500 grams and crush to peanut-sized fragments; (2) heat for 30 minutes to dry excess moisture; (3) while still hot immerse in cleaning solvent for 30 minutes and then drain off; (4) add boiling water and a spoonful of household detergent, let stand for 30 minutes and wash through a 200 mesh (.074 mm. opening) screen; (5) add hot water with $NaCO_3$ and boil for one hour; (6) pour sample into pint jar, place on roller for about 20 minutes, then again wash through screen; (7) check sample and if not clean repeat steps 5–7.

The entire washed sample was then ex-



TEXT-FIG. 2—Geologic map of the southeastern part of the Redding Quadrangle showing foraminiferal sample localities.



TEXT-FIG. 3—Stratigraphic column showing characteristic foraminiferal assemblages and diagnostic megafossils.

TEXT-FIG. 2—Geologic map of the southeastern part of the Redding Quadrangle showing foraminiferal sample localities.

amined under the microscope on a gridded picking tray and the number of individuals of each species counted. With a few of the more prolific samples this process was hastened by dividing the sample with a microsplitter to a suitable volume. Concentration of foraminiferal tests by means of a carbon tetrachloride separation process proved impractical, for many of the calcareous perforate tests and most of the arenaceous tests were filled and consequently would not float.

FAUNAL CHARACTERISTICS

Following Galloway's classification, 12 families, 43 genera and 90 species—22 of which are new—are represented in the section studied. One new name is proposed. Most of the species have been previously described from the Cretaceous of Europe—many by Reuss in the latter nineteenth century—and the American Gulf Coastal region. Statistical information related to these is presented in two tables.

The stratigraphic range and percentage abundance of each species is given in Table 1. Species with similar ranges are grouped accordingly. Two very distinct faunas may be recognized. The first occurs in rocks of Member II that crop out near the community of Bella Vista. Most of the species in this fauna occur only in Member II. The second occurs in strata of Members IV and VI that crop out in the many stream valleys to the north and east of the town of Millville. While the Bella Vista fauna is relatively small—comprised of only 24 species—it is very distinctive and easily recognized. There are 76 species in the fauna of Members IV and VI, 10 of which are also common to the Member II fauna. Two subfaunas characterized by species restricted to Members IV and VI respectively may be recognized. Those species found only in Member VI, however, are few and occur too rarely to make this subfauna easily recognized. Foraminifers that are most characteristic of the two faunas and subfaunas are listed in Text-figure 3 with selected diagnostic megafossil species..

Table 2 gives the relationship of the various groups of foraminifers by cumulative percentage graphs and also the total number of specimens and species from each 500 gram sample. Representatives of arenaceous species are most abundant, averaging only slightly less than 50% of the total specimens in each sample. This percentage is some-

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EXPLANATION OF PLATE 43

FIG. *1a,b—Psammosphaera laevigata* White. *1a*, side view; *1b*, edge view; both ×48. Hypotype: UCLA no. 26580; loc. no. 90.

2a,b—Bathysiphon vitta Nauss. *2a*, side view; *2b*, terminal view; both ×28. Hypotype: UCLA no. 26582; loc. no. 16.

3a,b—Bathysiphon brosgei Tappan. *3a*, side view; *3b*, terminal view; both ×28. Hypotype: UCLA no. 26581; loc. no. 25.

4a,b—Trochamminoides cf. *T. velascoensis* Cushman. *4a*, side view; *4b*, edge view; both ×28. Hypotype: UCLA no. 26585; loc. no. 65.

5a,b—Haplophragmoides excavata Cushman & Waters. *5a*, side view; *5b*, edge view; both ×48. Hypotype: UCLA no. 26589; loc. no. 58.

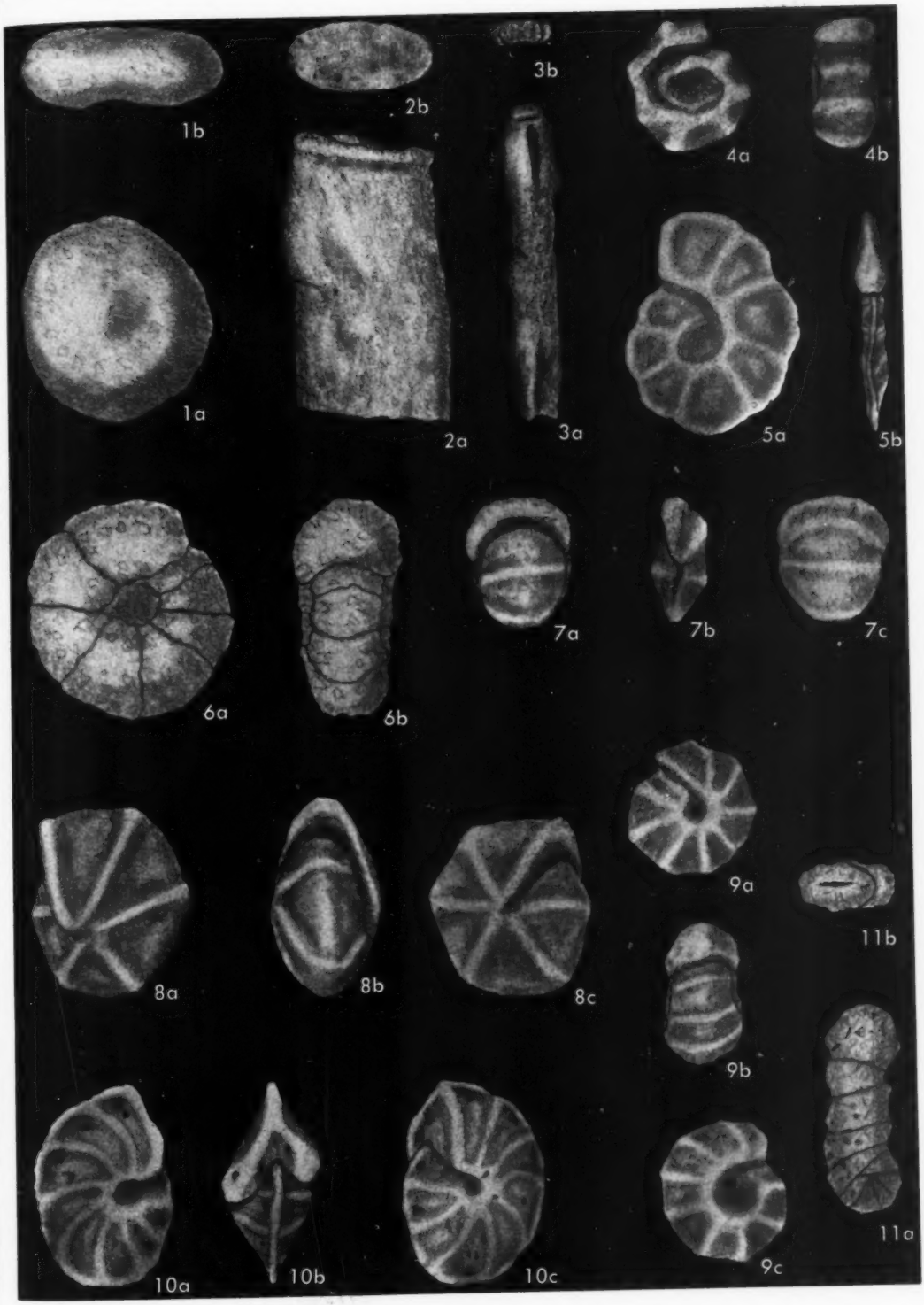
6a,b—Haplophragmoides fraseri Wickenden. *6a*, side view; *6b*, edge view; both ×48. Hypotype: UCLA no. 26590; loc. no. 11.

7a–c,8a–c—Cribrostomoides cretacea Cushman & Goudkoff. *7a,c*, opposite edge view; *7b*, side view. *8a–c*, opposite side views; *8b*, edge view. Hypotypes: Fig. *7*—UCLA no. 26594, crushed in plane of axis; ×28. Fig. *8*—UCLA no. 26595, crushed oblique to axis; ×50; both loc. no. 29.

9a–c—Haplophragmoides cf. *H. glabra* Cushman & Waters. *9a–c*, opposite side views; *9b*, edge view; all ×28. Hypotype: UCLA no. 26591; loc. no. 89.

10a–c—Cribrostomoides californiensis Trujillo, sp. nov. *10a–c*, opposite side views; *10b*, edge view; all ×45. Holotype: UCLA no. 26592; loc. no. 90.

11a,b—Ammobaculites subcretacea Cushman & Alexander. *11a*, side view; *11b*, terminal view; both ×24. Hypotype: UCLA no. 26596; loc. no. 15.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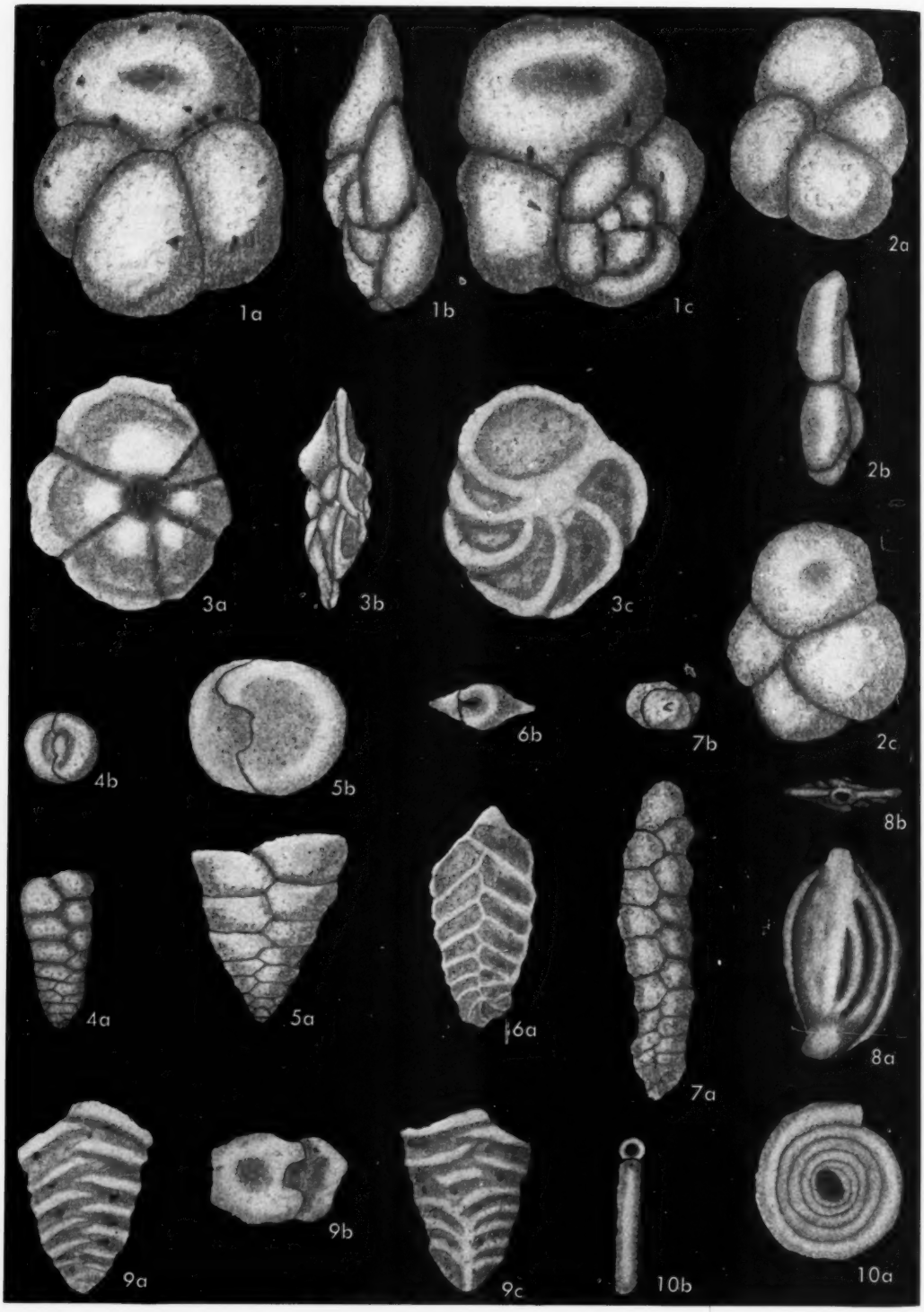
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7b
8a
8b
9a
9b
9c
10a
10b

what higher in the basal part and lower in the upper part of each member, a probable consequence of a changing depositional environment as is discussed in the section on paleoecology. In contrast, the number of arenaceous species in each sample makes up a smaller percentage than the number of arenaceous specimens, notably in Member II. A more striking contrast is exhibited by the Nodosariidae which constitute an appreciable percentage of specimens throughout the three members. This points out the fact that most species in the family are of rare occurrence and generally speaking, are unimportant for correlation purposes.

As opposed to the preceding, the groups composed of Rotaliidae and planktonic species are fairly consistent in occurrence both in percentage of specimens and species. The former is represented by only one species in Member II, but several distinctive species make it an important group in Members IV and VI. The planktonic species are important components of the Member II fauna and the Member IV subfauna, with only one long-ranging species present in Member VI. The group designated as "all others" is composed entirely of the family Ceratobuliminidae in Member II; the Ceratobuliminidae, Heterohelicidae and Pleurostomellidae in Member IV; while the Ceratobuliminidae and Pleurostomellidae represent the group in Member VI.

In all of the aforementioned groups the percentage of species remains more consistent than the percentage of specimens. The total number of species is quite variable, however, with 9 the least number and 53 the greatest number in a sample. The extreme paucity of foraminifers becomes apparent when one realizes that with 500 gram samples the number of specimens per sample varies from only 21 to a maximum of about 1000.

PALEOECOLOGY

A general interpretation of the environments represented by the Foraminifera under study may be made by using information obtained from groups of living foraminifers whose ancient counterparts lived in the Late Cretaceous seas. Table 2 gives a graphical presentation of the four groups used to make such an interpretation. These, excluding the group referred to as "all others," comprise about 90% of the fauna throughout the section studied.

There is a notable drop in the percentage of arenaceous forms in the upper part of each unit, and in Members II and IV there is a corresponding increase in the planktonic

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EXPLANATION OF PLATE 44

FIG. *1a–c—Trochammina böhmi* Franke. *1a*, umbilical view; *1b*, edge view; *1c*, spiral view; all ×48. Hypotype: UCLA no. 26586; loc. no. 81.

2a–c—Trochammina trifolia (Egger). *2a*, umbilical view; *2b*, edge view; *2c*, spiral view; all ×48. Hypotype: UCLA no. 26588, loc. no. 81.

3a–c—Trochammina texana Cushman & Waters. *3a*, umbilical view; *3b*, edge view; *3c*, spiral view; all ×52. Hypotype: UCLA no. 26587; loc. no. 40.

4a,b—Dorothia ellisorae (Cushman). *4a*, side view; *4b*, terminal view; both ×45. Hypotype: UCLA no. 26599; loc. no. 64.

5a,b—Dorothia oxycona (Reuss). *5a*, side view; *5b*, terminal view; both ×40. Hypotype: UCLA no. 26600; loc. no. 20.

6a,b—Spiroplectammina chicoana Lalicker. *6a*, side view; *6b*, terminal view; both ×55. Hypotype: UCLA no. 26601; loc. no. 90.

7a,b—Gaudryina foeda (Reuss). *7a*, side view; *7b*, terminal view; both ×52. Hypotype: UCLA no. 26597; loc. no. 13.

8a,b—Silicosigmoilina futabaensis Asano. *8a*, side view; *8b*, terminal view; both ×52. Hypotype: UCLA no. 26584; loc. no. 53.

9a–c—Gaudryina pyramidata Cushman. *9a,c*, opposite side views; *9b*, terminal view; all ×28. Hypotype: UCLA no. 26598; loc. no. 35.

10a,b—Spirillina minima Schacko. *10a*, side view; *10b*, edge view; both ×48. Hypotype: UCLA no. 26583; loc. no. 63.

TABLE *1*—Percentage abundances and stratigraphic ranges of species.

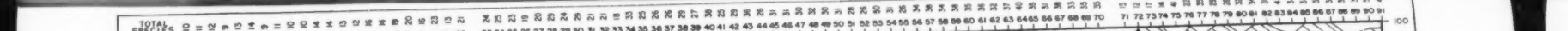
PERCENTAGE ABUNDANCES AND STRATIGRAPHIC RANGES OF THE UPPER CRETACEOUS FORAMINIFERA FROM NEAR REDDING, SHASTA COUNTY, CALIFORNIA — E.F. TRUJILLO

P = <1/50 per cent; – = Absent within range

MEMBER II | MEMBER IV | MEMBER VI

SPECIES — LOCALITY

Ammobaculites subcretaceo Cushman and Alexander
Planularia bachi (Roemer)
Marginulina troedssoni Bratzen
Dentalina bighornensis (Young)
Rugoglobigerina praehelvetica Trujillo, sp. nov.
Haplophragmoides fraseri Wickenden
Anomalina complanata Reuss
Frondicularia chapmani Perner
Lamarckina reedana Trujillo, sp. nov.
Höglundina lecuneae (Loeblich and Tappan)
Globotruncana schneegansi Sigal
Globotruncana helvetica Bolli
Globotruncana renzi Gandolfi
Lamarckina stormi Bratzen
Lenticulina pseudo-secans (Cushman)
Dentalina anguaticostata Cushman
Vaginulina modesta (Reuss)
Lenticulina warregoensis Crespin
Höglundina supracretacea (ten Dam)
Gaudryina foeda (Reuss)
Dorothia axgoodi (Reuss)
Bathysiphon vitta Nauss
Globotruncana linneiana (d'Orbigny)
Lenticulina modesta (Bandy)
Gyroidina nitida (Reuss)
Linguline californiensis Trujillo, sp. nov.
Vaginulina cf. *V. delicatocostata* Bartenstein and Brand
Praeglobotruncana hanselbilli Trujillo, sp. nov.
Marginulina obliquimedus Bandy
Tubitextularia cf. *T. cretacea* (Cushman)
Dentalina cf. *D. megalopolitana* Reuss
Nodosaria orthophragma Egger
Nodosaria aspera Reuss
Spirillina minima Schacko
Rugoglobigerina hilgi Trujillo, sp. nov.
Heterohelix globulosa (Ehrenberg)
Globotruncana canaliculata (Reuss), sensu stricto
Ceratobulimina cretacea Cushman and Harris
Cibicides ammonoides (Reuss)
Eponides greatvalleyensis Trujillo, sp. nov.
Dentalina peracuta (Reuss)
Bathysiphon brosgei Tappan
Trochamminoides cf. *T. velascoensis* Cushman
Cribrostomoides cretacea Cushman and Goudkoff
Haplophragmoides cf. *H. glabra* Cushman and Waters
Trochammina trifolia (Egger)
Gaudryina pyramidata Cushman
Lenticulina macrodisca (Reuss)
Astacolus polandensis Trujillo, nom. nov.
Nodosaria spinifera Cushman and Campbell
Eponides bandyi Trujillo, sp. nov.
Anomalina pepenoei Trujillo, sp. nov.
Pleurostomella greatvalleyensis Trujillo, sp. nov.
Saracenaria cancrebensis Trujillo, sp. nov.
Haplophragmoides excavata Cushman and Waters
Dorothia elliserae (Cushman and Harris)
Planularia cf. *P. simondsi* (Carsey)
Cribrostomoides californiensis Trujillo, sp. nov.
Dentalina coelivillensis Peterson
Psammosphaera laevigata White
Silicosigmoilina futabaensis Asano
Valvulineria marianosi Trujillo, sp. nov.
Marginulinopsis praetschoppi Trujillo, sp. nov.
Dentalina catenula Reuss
Frondicularia durrelli Trujillo, sp. nov.
Pleurostomella subnodosa Reuss
Nodosarella wintereri Trujillo, sp. nov.
Trochammina bohmi Franke
Gyroidina floreallis White
Saracenaria tenuisima ten Dam and Sigal
Lenticuline futabaensis (Asano)
Eponides birdi Trujillo, sp. nov.
Spiroplectammina chicoana Loeblich
Saracenaria triangularis d'Orbigny
Eponides goudkoffi Trujillo, sp. nov.
Astacolus jarvisi (Cushman)
Alabamina jimgrothi Trujillo, sp. nov.
Linguline lucillae Trujillo, sp. nov.
Astacolus umbonatus (Loeblich)
Lenticuline californiensis Trujillo, sp. nov.
Planularia arikadelensis Bratzen
Pectoglandulina pygmaea (Reuss)
Quadrimorphina allomorphinoides (Reuss)
Nodosaria tenuicosta Reuss
Vaginulinopsis reddingensis Trujillo, sp. nov.
Marginulina laiseae Trujillo, sp. nov.
Trochammina texana Cushman and Waters
Kyphopyxa christneri (Carsey)
Pectoglandulina mutabilis (Reuss)



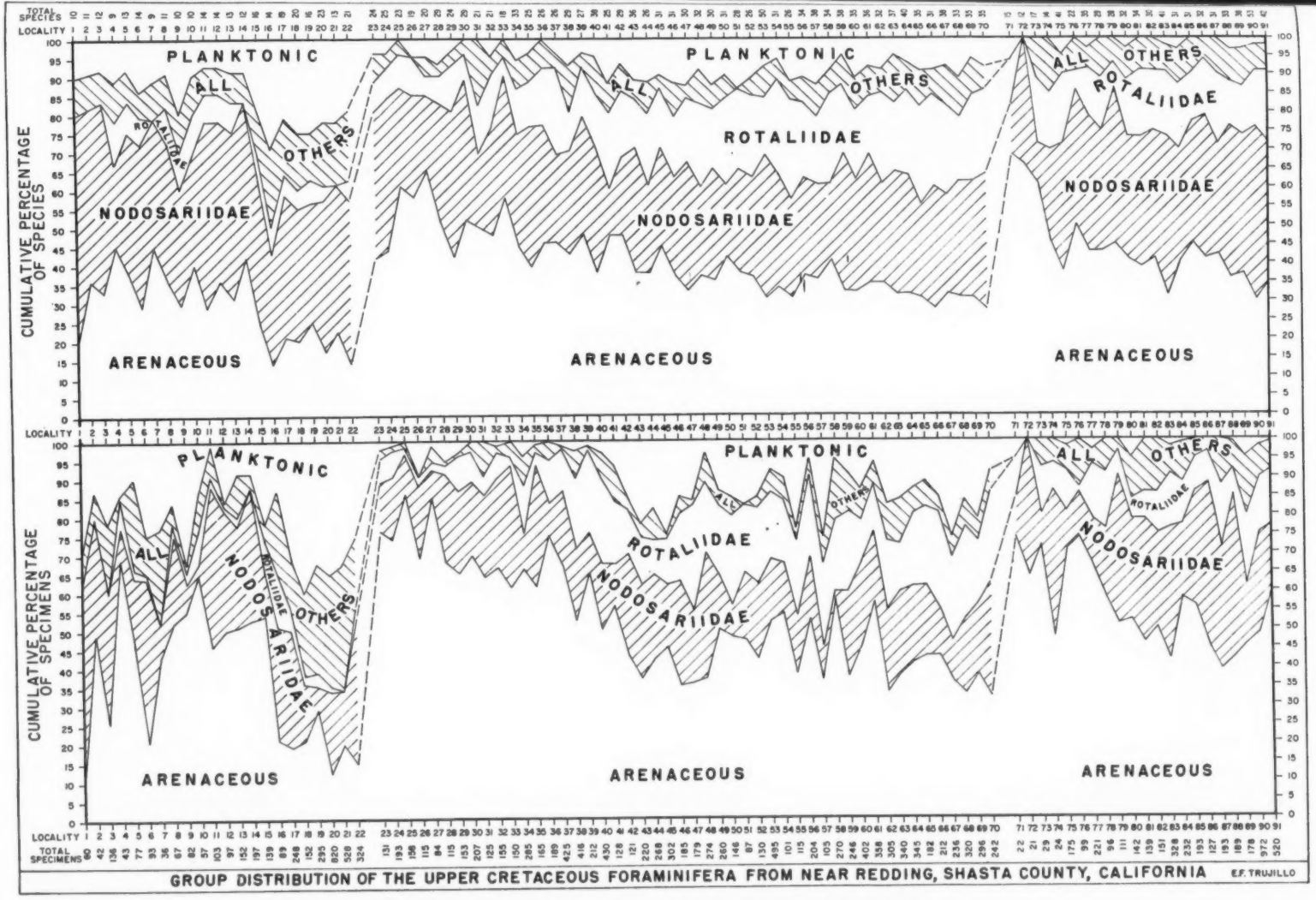


TABLE 2—Group distribution of Upper Cretaceous Foraminifera.

element. In Member II the percentage abundance of the planktonic group fluctuates around 15% near the base and 30% near the top; in Member IV it is about 5% near the base and comprises about 15% in the upper portion; while in Member VI it is unimportant throughout. Lowman (1949, fig. 13) shows that planktonic species in the Gulf of Mexico comprise less than 5% of the fauna in water less than 120 feet deep, then increases slightly but fluctuates at about 15% to 1200 feet after which it increases rapidly. On this basis the depositional site would appear to have been outer sublittoral (200–600′) for Member II; inner sublittoral (low tide-200′) for the lower part of Member IV and outer sublittoral for the upper part; while an inner to outer sublittoral zone of deposition is indicated for Member VI. The presence of *Globotruncana linneiana* (d'Orbigny) throughout all three members even in the absence of other planktonic species might indicate it lived nearer the surface and would not have been affected by fluctuations in depth. This affinity for particular depths of water is displayed by Recent planktonic species of Foraminifera as pointed out by Phleger (1945). There are therefore different concentrations of various species at certain depths as demonstrated by Phleger (1951, p. 35, table 9).

The Rotaliidae group is inconsequential throughout Member II; it represents about 5% near the base of Member IV and increases to about 15–20% in the upper part; while it comprises roughly 10% of the fauna in Member VI. Again referring to Lowman's figure 13, the Rotaliidae constitute between 5% and 20% of the fauna in depths of 100 feet to 300 feet, becoming negligible at greater depths. Thus these criteria point to depths of deposition corresponding to those determined by the planktonic element.

The Nodosariidae are of little use, for they are scarcely mentioned in Recent ecologic studies. Table 2 shows that this group makes up a large percentage of species but is represented by a much smaller percentage of specimens. Should the reverse be true one would infer that the group lived in its customary environment. The relatively large number of species represented by few individuals could be accounted for if one assumed the ecologic setting unsuitable, but that the natural habitat of the group was nearby. A few individuals of each species would naturally be introduced into the unsuitable environment even though they would not thrive.

Any conclusion regarding the paleoecology of the area must satisfactorily account for the large percentage of arenaceous specimens. While the arenaceous group is as a whole the most abundant, it must be kept in mind that this is a relative abundance; for in relation to volume of sediments it also is rare compared with what is generally considered a prolific fauna. It may therefore be said that the importance of the group is attained not so much by its own abundance as by the scarce occurrences of the other groups.

The papers on ecology of Recent Gulf Coast Foraminifera by Lowman (1949), Phleger & Walton (1950), Ellison (1951), Phleger (1954), and Bandy (1956), indicate that such arenaceous genera as *Ammobaculites*, *Haplophragmoides*, and *Trochammina* have a wide tolerance for changes in salinity and are commonly the only representatives found in lagoons and brackish water environments. This fact does not indicate that the above genera are restricted to such an environment, for they and other genera of the group occur in very shallow to bathyal deposits. It indicates only that an environmental factor or factors inhibited the growth of other foraminifers. While salinity is no doubt a factor, the amount of water turbidity may also be quite significant in near shore areas, as substantiated by Parker (1954, p. 472,478) in her observations of the Mississippi delta. Tappan (1951, p. 4) considered that muddied water was the responsible factor for the dominantly arenaceous fauna from northern Alaska..

Such an explanation may apply to the Redding area. It would account not only for the relatively large abundance of the arenaceous group, but also for the paucity of all foraminifers per gram weight of sediment. Inasmuch as sunlight either directly or indirectly dictates productivity of marine life, the diminishment of sunlight penetration by turbid water would bring about a like reduction in numbers of foraminifers.

On this basis one would not assume the shales of the Redding area to be valuable as a petroleum source; for the restriction of sunlight would curtail the high organic activity necessary for the formation of sufficient hydrocarbon material. This interpretation is further supported by the increase in abundance of the arenaceous group near the base of each shale member, for the rapid deposition associated with the underlying sandstone units would create a more turbid condition that would continue with lessening effect during the deposition of the basal portion of the shale strata.

Discussions by Reed (1933) and Anderson (1958) indicate the structural relationships and highlands bordering the Great Valley during Late Cretaceous time were similar to those of the present. The trough received sediments primarily from the west, but at various intervals the eastern highlands were also important contributors (Goudkoff, 1945, p. 1004). The presence of Turonian age strand lines in the Cow Creek area as reported by Anderson (1958, p. 78) indicates the northeast shore line was not far east of the area of this study.

CORRELATION AND AGE

For correlation of Upper Cretaceous marine rocks it is generally agreed that ammonites and orbulinid foraminifers, especially species of the genus *Globotruncana*, furnish the best means. Unfortunately, tratigraphically restricted species of *Globotruncana* occur only in Member II, and other species of the Orbulinidae that are restricted to Member IV have not been previously described. Therefore, the ages to which the Upper Cretaceous outcrops have been referred are principally determined by ammonite evidence. W. P. Popenoe and T. Matsumoto generously furnished the writer with their age determinations and names of diagnostic megafossils from each member including the three sandstone members which are devoid of Foraminifera. Text-fig. 3 shows the age and other pertinent details of each member and lists the characteristic assemblages of Foraminifera as well as the selected diagnostic megafossil species.

Three species of *Globotruncana*—*G. helvetica*, *G. renzi* and *G. schneegansi*—indicate a Turonian age for Member II, and ammonite evidence further restricts it to the Middle Turonian. While the above species of *Globotruncana* were found only in samples from near the contact with Member III this is probably not their true range for elsewhere they range throughout the Turonian. It is probable that their sudden appearance in Member II is a result of an environmental peculiarity. The species undoubtedly lived during part of the time in which Member III was being deposited.

The foraminifers occurring in Members IV and VI are predominantly those that have been reported in the same part of the Senonian in Europe and the Gulf Coast region. Thus, it may be seen that while the European substages cannot be determined by Foraminifera as readily as with the ammonites, the fauna of Member II is Turonian and the subfaunas of Members IV and VI respectively correspond to the Coniacian and Santonian as determined by the megafossils. There is a distinct difference in the faunal aspects of the Turonian and Senonian stages, reflecting the sharp stratigraphic and faunal break upon which the divisions in Europe were based and which is also present in California. Because of this feature, the European stage names have been applied rather than the less well known California foraminiferal stage names of Goudkoff (1945).

Goudkoff's zones (1945, table II) are not readily recognized in the Redding area. *Planularia kochii* (Roemer) is given as one of the characteristic species of the Lower Cachenian stage, G-2 zone, occurring with other characteristic species as *Gaudryina pyramidata* Cushman and the rarer species *Gyroidina florealis* White. In the Redding area *P. kochii* occurs in the Middle Turonian and the latter two are found only in the Coniacian and Santonian. *Astacolus jarvisi* (Cushman) is listed by Goudkoff as not occurring with *G. pyramidata*, yet they occur together throughout the Coniacian and Santonian of Redding. *Dorothia oxycona* (Reuss) supposedly occurs most characteristically in the E zone of the Tracian stage (Campanian), but in the Redding area it occurs most abundantly in Member II with *P. kochii*. There are similar discrepancies in the zonation as shown by the Redding fauna

and other California Upper Cretaceous faunas examined by the writer. Goudkoff (1945, table I and text-fig. 2) considered Member I to be within the Delevanian stage, equivalent to the Gulf Coast Woodbine Group (Cenomanian), and Members II–VI within the Cachenian stage, equivalent to the Eagle Ford Group (Turonian). This correlation with the Gulf Coast Upper Cretaceous may not have been intended, however, for the Austin Group (Coniacian-Santonian) is not listed in the table and is the true equivalent of Members IV–VI. Members I–III correspond to a threefold division of the Turonian.

SYSTEMATIC DESCRIPTIONS

Species are arranged systematically, based upon the classification of Galloway, 1933. Types of species are deposited in the Invertebrate Paleontological Collection of the University of California, Los Angeles.

Order FORMINIFERA d'Orbigny 1826
Family ASTRORHIZIDAE Brady, 1881
Genus PSAMMOSPHAERA Schulze, 1875
PSAMMOSPHAERA LAEVIGATA White
Pl. 43, figs. 1a,b

Psammosphaera laevigata WHITE, 1928, Jour. Paleontology, v. 2, p. 183, pl. 27, fig. 1; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 14 (not figured).

The shape of the test of *Psammosphaera laevigata* is discoidal, with sides nearly parallel or slightly convex, periphery smooth and edge rounded. A unilocular spheroid forms the chamber. The wall is arenaceous, of medium coarseness, and is smoothly finished. No general aperture is observable. The hypotype measures 0.65 mm. in diameter, and 0.25 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The original types were from the lower Velasco Formation (Paleocene) of the Tampico Embayment near Tantoquita, Mexico.

Genus BATHYSIPHON M. Sars, 1872
BATHYSIPHON BROSGEI Tappan
Pl. 43, figs. 3a,b

Bathysiphon brosgei TAPPAN, 1958, U. S. Natl. Mus. Bull. 215, p. 202, pl. 65, figs. 1–5.

The shape of the test of *Bathysiphon brosgei* is elongate, consisting of an undivided tubular chamber that is commonly straight but rarely somewhat irregularly bent or curved. The wall is finely agglutinated with considerable cement, rarely smoothly finished, and the surface may have irregularly spaced transverse growth wrinkles. Aperture is rounded, at the open end of the tubular chamber. The hypotype measures 1.70 mm. in length, 0.25 mm. in breadth, and 0.13 mm. in thickness.

Remarks.—It is probable that this species does occur in the Gulf Coastal region and only by unfortunate circumstance was a limonitic fragment selected from a true *Bathysiphon* fauna and mistakenly illustrated as the holotype of *Bathysiphon alexanderi* Cushman; for Tappan (see synonymy above) found the holotype of *B. alexanderi* to be an inorganic limonitic stick and not a foraminifer. She proposed the name *Bathysiphon brosgei* for specimens from Alaska that are very similar to the Redding specimens. All the specimens observed in this study were completely compressed, causing the apertural opening to be indiscernible.

Occurrence.—In the Redding area this species occurs throughout Member IV, Coniacian, and Member VI, Santonian, and is abundant in the Holz shale, Upper Turonian-Lower Campanian, of the Santa Ana Mountains, California. The original types are from a well core in the Topagoruk Formation, Middle and Upper Albian, west of Cape Simpson, northern Alaska, and in this area the species also ranges throughout the Fortress Mountain Formation, Upper Aptian to Lower Albian, and the Nanushuk Group, Middle Albian through Cenomanian.

BATHYSIPHON VITTA Nauss, 1947
Pl. 43, figs. 2a,b

Bathysiphon vitta NAUSS, 1947, Jour. Paleontology, v. 21, p. 334, pl. 48, fig. 4.

The shape of the test of *Bathysiphon vitta* is elongate, compressed, and the edges broadly rounded. The chamber is a simple tube with indistinct constrictions at regular intervals. The wall is arenaceous, fairly thin, composed of minute clear grains neatly joined in a white amorphous cement, and is covered with a black coating. Aperture is formed by the open ends of the test. The

hypotype measures 1.50 mm. in length, 0.90 mm. in breadth, and 0.38 mm. in thickness.

Remarks.—It is probable that the holotype was originally cylindrical, and the above description is of a crushed specimen, as are most of the fossil representatives of this genus. The California specimens seldom have the black coloring.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The species occurs abundantly in the Holz shale, Upper Turonian-Lower Campanian, of the Santa Ana Mountains, California. Some of the reported Gulf Coast and California Cretaceous occurrences of the Miocene species *B. taurinensis* Sacco, could probably better be referred to this species. The original types are from the Lea Park shale of Late Cretaceous age, in the Vermilion area, Alberta, Canada (well core).

Family SPIRILLINIDAE Reuss, 1861
Genus SPIRILLINA Ehrenberg, 1843
SPIRILLINA MINIMA Schacko
Pl. 44, figs. 10a,b

Spirillina minima SCHACKO, 1892, Ver. Freunde Naturg. Mecklenburg, Archiv, Gustrow, Jahrg. 45 (1891), Abth. 2, p. 159, pl. 1, fig. 4; FRANKE, 1928, Preuss. Geol. Landesanst., Abh., Berlin, N.F., Heft 111, p. 16,17, pl. 1, figs. 21a,b; TAPPAN, 1940, Jour. Paleontology, v. 14, p. 119, pl. 19, fig. 8; FRIZZELL, 1954, Bur. Econ. Geol., Texas Univ., Rpt. Invest., no. 22, p. 122, pl. 18, fig. 24.

The shape of the test of *Spirillina minima* is tubular, closely coiled, planispiral, with rounded edge. The proloculum is large, rounded, and the second chamber is long and undivided. The wall is calcareous, perforate and smooth. Aperture is a rounded opening, formed by the open end of the tubular test. The hypotype measures 0.47 mm. in diameter, and 0.08 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian. On the Gulf Coast, this species occurs in the Duck Creek Formation, Upper Albian, and in the Grayson marl, Buda limestone and Maness shale of the Lower Cenomanian or Upper Albian. The holotype came from the Cenomanian of Mecklenburg, Germany.

Family RZEHAKINIDAE Cushman, 1933
Genus SILICOSIGMOILINA Cushman & Church, 1929
SILICOSIGMOILINA FUTABAENSIS Asano
Pl. 44, figs. 8a,b

Silicosigmoilina futabaensis ASANO, 1950, Pacific Science, Honolulu, v. 4, no. 2, p. 159, figs. 6,7.

The shape of the test of *Silicosigmoilina futabaensis* is oval in side view, compressed, with subacute edge. The chambers are arranged planispirally in the early portion, sigmoidal in the later stages. Sutures are initially indistinct, becoming fairly well marked between the later chambers but not deeply depressed. The wall is finely arenaceous, firmly cemented with siliceous cement, and white or light gray in color. The aperture is terminal, simple, without a tooth. The hypotype measures 0.65 mm. in length, 0.37 mm. in breadth, and 0.12 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The original types were from a Senonian well core from Yokouchi, Fukoshima Prefecture, Honshu Island, Japan.

Family TROCHAMMINIDAE Schwager, 1877
Genus TROCHAMMINOIDES Cushman, 1910
TROCHAMMINOIDES cf. T. VELASCOENSIS Cushman
Pl. 43, figs. 4a,b

Trochamminoides velascoensis CUSHMAN, 1926, Amer. Assoc. Petroleum Geologists, Bull., v. 10, pt. 1, no. 6, p. 583, pl. 15, fig. 2; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 19, pl. 2, figs. 7,8.

The shape of the test of *Trochamminoides velascoensis* is compressed, closely coiled and slightly inequilateral. There are about 8 chambers in the last-formed coil, those on the umbilical side overlapping slightly more than on the spiral side. The sutures are depressed. The wall is arenaceous, rather smoothly finished. The hypotype measures 0.62 mm. in diameter, 0.37 mm. in thickness.

Remarks.—All of the specimens of this study have apparently been slightly crushed causing the chambers to collapse and the sutures to appear raised. Because of these

discrepancies, the specimens have only been tentatively referred to this species.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The original types were from the Velasco shale, Paleocene, Hacienda El Limon, State of San Luis Potosi, Mexico.

Genus TROCHAMMINA Parker & Jones, 1859

TROCHAMMINA BÖHMI Franke

Pl. 44, figs. 1a–c

Trochammina böhmi FRANKE, 1928, Preuss. Geol. Landesanst., Abh., N.F., Heft 111, p. 174, pl. 15, fig. 24.

The shape of the test of *Trochammina böhmi* is discoidal, consisting of 1½–2 whorls that increase rapidly in breadth, with the spiral side rather convex and the umbilical side nearly flat. Chambers are flat, disc shaped, slightly overlapping, with the spiral side displaying about 6 in the first whorl that are gently inflated and 3–4 in the ultimate whorl, while only those of the last whorl are visible on the umbilical side. The sutures are distinct, depressed. Apertural openings are on the spiral side, at the outer indentations of the first whorl. The hypotype measures 0.95 mm. in length, 0.80 mm. in breadth, and 0.40 mm. in thickness.

Remarks.—The above description is a literal translation from the German text. The position of the apertures as given by Franke is, in the writer's opinion, rather questionable. Unfortunately, the holotype was not available for examination. Of the specimens observed, all fit the original description and figured spiral side exactly except that the aperture appears to be interiomarginal on the umbilical side as is usual for the genus; however, it is so indistinct as to make a definite statement unfeasible until better specimens are found and the holotype re-examined.

Occurrences.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The holotype is from the Emscher (Coniacian) of Westfalen, Germany.

TROCHAMMINA TEXANA Cushman & Waters

Pl. 44, figs. 3a–c

Trochammina texana CUSHMAN & WATERS, 1927, Cushman Lab. Foram. Research, Contr., v. 2, p. 85, pl. 11, fig. 8; CUSHMAN & TODD, 1943, *idem*, v. 19, p. 54, pl. 9, fig. 14; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 50, pl. 15, figs. 4,5; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 79, pl. 7, fig. 21.

The shape of the test of *Trochammina texana* is rotaloid, much compressed, and planoconvex, with the spiral side flattened or even slightly concave and the umbilical side slightly convex and umbilicate. Chambers are fairly distinct, with six in the last formed coil. The later chambers are more distinct and the earlier ones are less distinct. The borders of the last chambers are raised on the spiral side. The central portion of each is concave. The greatest thickness on the umbilical side is near the umbilical angle of each chamber. Sutures on the spiral side are indistinct except between the last two or three chambers, but are distinct and depressed on the umbilical side. The wall is finely arenaceous and has a smooth finish. The hypotype measures 0.68 mm. in length, 0.59 mm. in breadth, and 0.22 mm. in thickness.

Occurrences.—Studied specimens are from Member VI, Santonian. This species has been reported widely in Texas and Clark County, Arkansas, in rocks of Navarro (Maestrichtian) age. The original types were from the Navarro Formation near Quinlan, Hunt County, Texas.

TROCHAMMINA TRIFOLIA (Egger)

Pl. 44, figs. 2a–2c

Haplophragmium trifolium EGGER, 1900, K. Bayer Wiss. München, Math.-Phys. Cl., Abh., Bd. 21 (1902), Abt. 1 (1899), p. 137, pl. 1, figs. 10,11,32,52,53.

The shape of the test of *Trochammina trifolia* is discoidal, compressed, and small. There are three overlapping disc-shaped, cyclically arranged chambers with raised borders. The wall is arenaceous, of uniform grain size. The hypotype measures 0.65 mm. in length, 0.55 mm. in breadth, and 0.19 mm. in thickness.

Remarks.—While many of the specimens have three chambers as does the holotype, most do not, ranging from two to five. Furthermore, Egger described characteristics of specimens with collapsed chambers as the figured holotype displays. Considering these points, the specimens from the

Redding area are believed to be justifiably placed in this species.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. Egger listed occurrences in the Senonian and Cenomanian in the region of Oberbayern, Germany.

Genus HAPLOPHRAGMOIDES Cushman, 1910

HAPLOPHRAGMOIDES EXCAVATA Cushman & Waters

Pl. 43, figs. 5a,b

Haplophragmoides excavata CUSHMAN & WATERS, 1927, Cushman Lab. Foram. Research, Contr., v. 2, p. 82, pl. 10, fig. 3; CUSHMAN, 1927, Royal Soc. Canada Trans., 3d ser., v. 21, sec. 4, p. 128, pl. 1, fig. 1; CUSHMAN & JARVIS, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 12, pl. 3, fig. 1; CUSHMAN & HEDBERG, 1941, Cushman Lab. Foram. Research, Contr., v. 17, p. 82, pl. 21, fig. 1; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 21, pl. 2, figs. 13–15.

Haplophragmoides sp. CUSHMAN & JARVIS, 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 91, pl. 12, fig. 16.

Haplophragmoides excavatus FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 60, pl. 1, fig. 30.

The shape of the test of *Haplophragmoides excavata* is planispiral, close-coiled, compressed, with subacute edge. Chambers are distinct, with ten in the last formed coil of the adult, with the border of each distinctly thickened and the central portion depressed. Sutures are straight, radial, but not usually distinct. The wall is finely arenaceous, smoothly finished, with little cement, and light gray in color. The hypotype measures 0.70 mm. in length, 0.55 mm. in breadth, and 0.10 mm. in thickness.

Remarks.—The figured hypotype is one of the intermediate forms. All have been compressed, and those most compressed appear more evolute, no doubt from deformation; however, the least compressed have nearly the biconvexity and involuteness of the holotype.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. This species has been reported widely in the Navarro and Taylor of Texas, and in the Upper Cretaceous of Canada and Mexico. The original types were from the Navarro Formation (Maestrichtian) near Quinlan, Hunt County, Texas.

HAPLOPHRAGMOIDES FRASERI Wickenden

Pl. 43, figs. 6a,b

Haplophragmoides fraseri WICKENDEN, 1932, Royal Soc. Canada, Proc. Trans., ser. 3, v. 26, sec. 4, p. 86, pl. 1, fig. 2.

The shape of the test of *Haplophragmoides fraseri* is planispiral, umbilicate, not completely involute, with each coil overlapping only the previous one, and the periphery broad and well rounded. Chambers are distinct, with nine to ten in the last formed coil. The sutures are slightly curved, nearly radial and slightly depressed. The wall is smooth, composed of a few rather fine, angular grains of arenaceous material and much cement. Aperture is a low arch a little to one side of the plane of coiling, at the base of the last apertural face. The hypotype measures 0.65 mm. in diameter, and 0.35 mm. in thickness.

Remarks.—The specimens of this study are more coarsely arenaceous than apparently is the holotype; otherwise they appear to be indistinguishable.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The original types were from the Upper Cretaceous Bear Paw shale, east of Manyberries, Alberta Canada.

HAPLOPHRAGMOIDES cf. H. GLABRA Cushman & Waters

Pl. 43, figs. 9a–c

Haplophragmoides glabra CUSHMAN & WATERS, 1927, Cushman Lab. Foram. Research, Contr., v. 2, pt. 4, p. 83, pl. 10, fig. 6; CUSHMAN, 1927, Royal Soc. Canada Trans., 3d ser., v. 21, sec. 4, p. 129, pl. 1, fig. 4; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 20, pl. 2, figs. 16, 17.

Haplophragmoides glaber FRIZZELL, 1954. Bureau Econ. Geol., Texas Univ., Rept. Inv. no.22, p. 60, pl. 1, fig. 30.

The shape of the test of *Haplophragmoides glabra* is planispiral, close coiled, somewhat compressed and umbilicate with rounded periphery. The chambers are fairly distinct, rounded, evenly curved, with nine to eleven in the last formed coil of the adult. Sutures are slightly curved and depressed. Wall is finely arenaceous, smoothly finished, and dark gray in color. The hypotype measures 0.70 mm. in diameter, and 0.38 mm. in thickness.

Remarks.—The specimens of this study have all been crushed, losing their plane of symmetry and the chambers probably collapsed, making the sutures appear somewhat raised. Sections of specimens were prepared to better determine the apertural characteristics, and some appeared to have a *Cribrostomoides* type aperture; however, they have been tentatively placed in this species until more conclusive data are available.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species has been reported from Texas and Arkansas, in rocks of Navarro (Maestrichtian) age, and from the Upper Cretaceous of Saskatchewan, Canada. The original types were from the Navarro Formation near Quinlan, Hunt County, Texas.

Genus CRIBROSTOMOIDES Cushman, 1910

CRIBROSTOMOIDES CALIFORNIENSIS
Trujillo, sp. nov.
Pl. 43, figs. 10a–c

The shape of the test of *Cribrostomoides californiensis* is biconvex, planispiral, involute, slightly umbilicate but closely coiled with a nearly smooth periphery and acute edge. There are eight to ten chambers in the ultimate whorl, increasing slowly and regularly in size as added. The sutures are indistinct, nearly flush, and slightly curved. The wall is finely agglutinated, very smooth, with much cement, and white to light tan in color. Aperture is indistinct, at the base of the last septal face, seemingly a low arch with incipient development of pores. The holotype measures 0.70 mm. in length, 0.35 mm. in breadth, and 0.50 mm. in thickness.

Remarks.—This species may be recognized by the acute edge, indistinct sutures, very smooth wall, small umbilici and biconvex test.

Distortion has eliminated the plane of symmetry the specimens no doubt originally possessed, but whatever the resultant shape, the species is easily recognizable. The species occurs in most of the samples and should make a good Senonian marker, although the youngest occurrence was not determined in this study.

Unfigured paratypes.—UCLA no. 26593.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner, sec. 35, T32N, R2W, Shasta County, California. Other studied specimens are from Member IV, Coniacian, and Member VI, Santonian.

CRIBROSTOMOIDES CRETACEA
Cushman & Goudkoff
Pl. 43, figs. 7a–c, 8a–c

Cribrostomoides cretacea CUSHMAN & GOUDKOFF, 1944, Cushman Lab. Foram. Research, Contr., v. 20, p. 54, pl. 9, fig. 4; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists Bull., v. 29, p. 969 (list), p. 989.

Cribrostomoides (?) sp. CUSHMAN & GOUDKOFF, 1944, Cushman Lab. Foram. Research, Contr., v. 20, p. 55, pl. 9, fig. 5; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, p. 969 (list).

Barkerina cretacea FRIZZELL & SCHWARTZ, 1950, Missouri School Mines, Bull., Tech. ser., no. 76, p. 9.

The shape of the test of *Cribrostomoides cretacea* is subglobular, planispiral, closely coiled, involute, with a distinctly depressed umbilical region and broadly rounded periphery. There are eight to ten chambers in the adult coil, very slightly if at all inflated, and increasing very gradually in size as added. Sutures are fairly distinct, little if at all depressed. The wall is very finely arenaceous and smoothly finished. The aperture consists of several pores along the base of the apertural face in the adult specimen. The measurements of the hypotypes are: Plate 43, fig. 7—0.67 mm. in length, 0.60 mm. in breadth, and 0.30 mm. in thickness; Plate 43, fig. 8—0.60 mm. in length, 0.48 mm. in breadth, and 0.34 mm. in thickness.

Remarks.—All the specimens are quite badly distorted. The two illustrated specimens show the most common distortion, oblique and normal to the axis of coiling, with other specimens varying between these extremes. There are usually less chambers than in the holotype, but undistorted specimens from the Santa Ana Mountains are also fewer chambered.

Frizzell & Schwartz (1950, see synonymy above) included this species in the genus *Barkerina* Frizzell & Schwartz, 1950; how-

ever, sections of typical specimens—but not topotypes—and distorted specimens, do not show true partitions that would place them in this newer genus. In fact, the validity of the emendation of *Cribrostomoides* by Frizzell & Schwartz (1950, *op. cit.*, p. 10) so far as apertural characteristics are concerned is, in the writer's opinion, open to question, as the aperture in some specimens appears to be at the base and not above the base of the septal face and surrounded by it as in the emended description. Furthermore, the type species of *Cribrostomoides*—*C. bradyi* Cushman—as pointed out by Frizzell & Schwartz (1950, *op. cit.*, p. 3,4) is greatly variable in apertural development. Considering this, and the lack of partitions and probable lack of apertures within the septal face of *C. cretacea*, combined with the fact that Frizzell & Schwartz did not have specimens either of *C. cretacea* or *C. trinitaensis* Cushman & Jarvis (also included by them in their new genus *Barkerina*) leaves little, if any, valid grounds upon which to make a generic emendation.

This is the most abundant species found in this study, and is present in every sample within its range.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species occurs commonly in other sections of the California Senonian. The original types were from the "Chico" (Upper Cretaceous Series) at Martinez Creek, Fresno County, California.

Genus AMMOBACULITES Cushman, 1910
AMMOBACULITES SUBCRETACEA Cushman & Alexander
Pl, 43, figs. 11a,b

Ammobaculites subcretacea CUSHMAN & ALEXANDER, 1930, Cushman Lab. Foram. Research, Contr., v. 6, p. 6, pl. 2, figs. 9,10.

Ammobaculites subcretaceus ALBRITTON, 1937, Jour. Paleontology, v. 11, p. 20, pl. 4, figs. 3,4; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 23, pl. 3, figs. 18,19; LOEBLICH & TAPPAN, 1949, Jour. Paleontology, v. 23, p. 251, pl. 46, figs. 9,13; STEAD, 1951, Texas Jour. Science, v. 3, p. 589, pl. 1, figs. 7,9; FRIZZELL, 1954, Bur. Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 62, pl. 2, figs. 27,28.

The shape of the test of *Ammobaculites subcretacea* is small, compressed, with early portion closely coiled and the later portion uncoiled. There are three to four chambers in the straight linear series that only slightly increase in diameter as added, the greatest diameter of each below the middle. Sutures are indistinct in the coiled portion, slightly depressed in the uncoiled portion. The wall is arenaceous, composed of coarse, angular, clear grains with a small amount of light gray cement and surface somewhat roughened. Aperture is terminal and narrowly elliptical. The hypotype measures 1.30 mm. in length, 0.50 mm. in breadth of final chamber, and 0.35 mm. in thickness of last chamber.

Occurrence.—Studied specimens are from Member II, Middle Turonian. On the Gulf Coast the species is reported from the Eagle Ford (Turonian), Woodbine (Cenomanian) and extensively in the Commanche Series (Albian-? Lower Cenomanian). The holotype is from the Middle Albian Goodland Formation, Lake Worth, near Fort Worth, Texas.

Family VERNEUILINIDAE Cushman, 1911
Genus GAUDRYINA d'Orbigny, 1839
GAUDRYINA FOEDA (Reuss)
Pl, 44, figs. 7a,b

Textularia foeda REUSS, 1846, Versteinerungen böhm. Kreide formation, pt. 2, p. 109. pl. 43, figs. 12,13; FRANKE, 1928, Preuss, geol. Landesanst. Abh., new ser., v. 111, p. 133, pl. 12, fig. 6.

Textularia concinna CUSHMAN & JARVIS, 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 91, pl. 13, fig. 1; ——, 1928, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 15, pl. 4, figs. 1,2.

Gaudryina filiformis CUSHMAN & JARVIS, Cushman Lab. Foram. Research, Contr., v. 4, p. 92, pl. 13, fig. 2; ——, 1928, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 16, pl. 4, fig. 5.

Gaudryina foeda CUSHMAN, 1932, Cushman Lab. Foram. Research, Contr., v. 8, p. 90; ——, 1937, *idem*, Special Pub. 7, p. 38, pl. 5, figs. 8–16; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 32, pl. 7, figs. 12,13; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 70, pl. 5, figs. 17,18.

The shape of the test of *Gaudryina foeda* is lanceolate, with the greatest width near the apertural end. The earliest formed chambers are apparently triserially arranged, becoming biserial during the greater final portion in which they are fairly distinct and slightly inflated. Sutures are nearly horizontal. The

wall is arenaceous, of rather large grains, and easily distorted. Aperture is terminal, elongate, at the inner margin of the last chamber. The hypotype measures 0.95 mm. in length. 0.20 mm. in greatest breadth, and 0.12 mm. in thickness.

Remarks.—There is a great variation in the specimens of this study, as has been reported for the species as a whole, much of which is no doubt due to deformation. Some specimens, as the one illustrated, tend to become uniserial, others are distinctly biserial and wide at the apertural end. It is thought best to consider these features a range of one species, inasmuch as they occur together, rather than place them in different species as has been done previously.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. This species also is reported extensively from the Senonian of the Gulf Coast and in younger rocks in Trinidad. The original types were from the Plänermergel (Cenomanian-Turonian) of Luschitz, Bohemia.

GAUDRYINA PYRAMIDATA Cushman
Pl. 44, figs. 9a–c

Gaudryina laevigata Franke var. *pyramidata* CUSHMAN, 1926, Amer. Assoc. Petroleum Geologists, Bull., v. 10, pt. 1, no. 6, p. 587, pl. 16, fig. 8; WHITE, 1928, Jour. Paleontology, v. 2, p. 313, pl. 42, fig. 7; CUSHMAN & JARVIS, 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 92, pl. 13, fig. 6; ——, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 18, pl. 5, fig. 3; CUSHMAN, 1932, Jour. Paleontology, v. 6, p. 333.

Gaudryina (*Pseudogaudryina*) *pyramidata* CUSHMAN, 1937, Cushman Lab. Foram. Research, Special Pub. 7, p. 87, pl. 12, fig. 13; CUSHMAN & GOUDKOFF, 1944, *idem*, Contr., v. 20, p. 56, pl. 9, figs. 7,8; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 36, pl. 8, fig. 14.

Gaudryina pyramidata GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, p. 969 (list.)

The shape of the test of *Gaudryina pyramidata* is somewhat longer than broad, triangular in initial transverse section, becoming subrectangular in the later portion. The chambers are distinct, slightly inflated, triserial initially, the major final portion biserial, with the series of one side squarely truncate, the other less so. Sutures are distinct, slightly depressed. The wall is arenaceous, usually with a smooth surface. The aperture is a low opening in a semicircular re-entrant of the inner margin of the final chamber. The hypotype measures 1.00 mm. in length, 0.75 mm. in breadth of last chamber, 0.51 mm. in thickness of last chamber.

Remarks.—Several specimens were sent to Miss Ruth Todd, U. S. National Museum, Washington, D. C., for comparison with types. She affirmed these to be identical to those reported from the Rumsey Hills by Cushman & Goudkoff (1944), and from Trinidad by Cushman & Jarvis (1928); however, whether these are the same as the holotype she was unable to determine, as the surface of the holotype is covered with matrix (and therefore the type illustration is apparently not too reliable). The sutures of the specimens of this study appear raised, but as pointed out by Miss Todd, another interpretation would be that the chambers are quite inflated—the upper part at least—and the suture depressed above this. Inasmuch as the general shape and cross section is the same as the holotype, it is thought best to follow this latter interpretation of the sutures and refer the specimens to this species as have the two above mentioned authors.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species has been reported from the Rumsey Hills, Sutter County, California, from the island of Trinidad and the Tampico Embayment region of Mexico. The holotype is from the Velasco shale, Paleocene, at Hacienda El Limon, State of San Luis Potosi, Mexico.

Genus DOROTHIA Plummer, 1931

Dorothia PLUMMER, 1931, Bureau Econ. Geol., Texas Univ. Bull., no. 3101, p. 130.

Marssonella CUSHMAN, 1933, Cushman Lab. Foram. Research, Contr., v. 9, pt. 2, p. 136.

"Test agglutinate, elongate, chambers of initial stage trochoid around the elongate axis of the complete test with more than three in the first one or more convolutions and with gradually decreasing number in successive convolutions till biseriality is attained and continues to the end of development; aperture in trochoid portion a low arch at the base of the septal face and directed into the umbilical depression, in biserial stage typically textularian."

Type species: *Dorothia bulleta* (Carsey) = *Gaudryina bulleta* Carsey, 1926 (original designation).

Remarks.—The preceding is the type description of the genus *Dorothia.* Following is the type description of *Marssonella* Cushman, 1933, the type species of which is *Marssonella oxycona* (Reuss) = *Gaudryina oxycona* Reuss, 1860 (original designation): "Test trochoid, round in section, early stages conical with four or five chambers to a whorl, later reduced to three, and in the adult to two in a whorl; chambers simple, undivided, apertural end flat or concave; wall arenaceous; aperture, a low elongate opening at the inner margin of the chamber, or extending into the chamber wall."

The genus *Marssonella* has been included as a junior symonym of *Dorothia* for several reasons. There is nothing in the type dedescription of *Marssonella* that will distinguish it from *Dorothia,* except for specific features that would be included in generic variations. For instance, the distinction of "four or five chambers to a whorl" in the early stages is included in the generic description of *Dorothia,* "with more than three in the first one or more convolutions." Galloway (1933, p. 216) and Cushman (1950, p. 137), err in their descriptions of *Dorothia* as having five or six chambers initially. The type species has that number initially, but a genus is based on the original description and not restricted to the generic characteristics found only in the type species, else a genus could include only one species. The type description does not limit the number of chambers in the initial whorls provided it is over three. Insofar as the flat or concave apertural end is concerned, this feature is not excluded as a characteristic of *Dorothia,* and is at best a distinguishing characteristic of a species. In fact, many of the Senonian specimens of *D. oxycona* (Ruess) in the Redding area have slightly convex apertural ends, and *D. ellisorae* (Cushman) has more representatives with convex apertural ends than with flat or concave ends. Considering these various points, it is believed that *Marssonella* cannot be distinguished from *Dorothia;* therefore, it does not constitute a valid biological genus and should be suppressed.

DOROTHIA ELLISORAE (Cushman)
Pl. 44, figs. 4a,b

Marssonella ellisorae CUSHMAN, 1936, Cushman Lab. Foram. Research Special Pub. 6, p. 44, pl. 4, fig. 11; ——, 1937, *idem,* Special Pub. 8, p. 60. pl. 6, figs. 19,20; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 44, pl. 12, figs. 8,9; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 75, pl. 6, fig. 16.

The shape of the test of *Dorothia ellisorae* is elongate, slender, with earliest portion tapering, later adult portion with sides nearly parallel, and rounded in section. The chambers are distinct, slightly inflated, of rather uniform shape and size, with four or five in the earliest whorls, becoming triserial and finally biserial in the adult portion. Sutures are distinct and slightly depressed. The wall is arenaceous and smoothly finished. The aperture is a low opening in a re-entrant at the base and inner margin of the final chamber. The hypotype measures 0.55 mm. in length, and 0.27 mm. in diameter of the last chambers.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species also is found in the Holz shale (Upper Turonian-Lower Campanian) of the Santa Ana Mountains, California. The holotype is from the Middle Campanian Pecan Gap chalk, Brazos Falls, Texas.

DOROTHIA OXYCONA (Reuss)
Pl. 44, figs. 5a,b

Gaudryina oxycona REUSS, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber, Bd. 40, p. 229, pl. 12, fig. 3; CUSHMAN & CHURCH, 1929, Calif. Acad. Science Proc., Ser. 4, v. 18, p. 501, pl. 36, figs. 3,4; CUSHMAN & JARVIS, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 18, pl. 5, figs. 1,2.

Marssonella oxycona CUSHMAN, 1933, Cushman Lab. Foram. Research, Contr., v. 9, p. 36, pl. 4, fig. 13; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, p. 968 (list); CUSHMAN, 1949, Maryland Dept. Geol., Mines and Water Res. Bull. 2, p. 248, pl. 21, fig. 11; HOFKER, 1949, Institut Royal des Sciences Nat. Belgique Mém. 112, p. 12, fig. 6; BANDY, 1951, Jour. Paleontology, v. 25, no. 4, p. 492, pl. 72, fig. 8; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 75, pl. 6, fig. 17.

Marssonella cf. *M. oxycona* SCHIJFSMA, 1946, Meded. van de Geologische. Stitchting, ser. c, v. 167, p. 38, pl. 1, fig. 12.

The shape of the test of *Dorothia oxycona*

is conical, oval in transverse section, with initial end pointed and apertural end truncate. The chambers are low, increasing slowly in height, with four to five per whorl initially, then reducing to three and finally biserial in the adult. Sutures are horizontal, and nearly flush. The wall is arenaceous, smoothly finished to slightly roughened. The aperture is a short and narrow opening at the inner base of the last chamber. The hypotype measures 0.70 mm. in length, 0.62 mm. in breadth, and 0.49 mm. in thickness.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. This species is present in the Holz shale, Upper Turonian-Lower Campanian, of the Santa Ana Mountains, California, in the Campanian of the Carlsbad area, San Diego County, California, widely throughout Texas in the Senonian and Maestrichtian, in the Upper Cretaceous of Peru, New Jersey and Europe, where it is also reported from the Upper Gault (Albian). The holotype is from Germany, but the type horizon and locality was undefined.

Family TEXTULARIIDAE d'Orbigny, 1846
Genus SPIROPLECTAMMINA Cushman, 1927
SPIROPLECTAMMINA CHICOANA Lalicker
Pl. 44, figs. 6a,b

Spiroplectammina chicoana LALICKER, 1935, Cushman Lab. Foram. Research, Contr., v. 11, p. 7, pl. 1, figs. 8,9.
Spiroplectammina anceps CUSHMAN & CHURCH, 1932, Proc. Calif. Acad. Science, ser. 4, v. 18, p. 500, pl. 36, figs. 1,2.
Spiroplectammina jarvisi CUSHMAN, 1939, Cushman Lab. Foram. Research, Contr., v. 15, p. 90, pl. 16, fig. 1; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 29, pl. 6, fig. 16.

The shape of the test of *Spiroplectammina chicoana* is much compressed, rapidly increasing in breadth from the initial end, with greatest breadth near the apertural end and thickest near the median portion, thence thinning toward the periphery. Chambers are numerous, coiled in the early portion, later becoming biserial, with the shape remaining low, broad, and depressed throughout. Sutures are distinct, limbate, especially near the apertural end, and are straight, somewhat oblique, and form an angle of twenty-five degrees with the horizontal. The wall is coarsely arenaceous but smoothly finished. A low opening at the base of the inner median margin of the last chamber forms the aperture. The hypotype measures 0.63 mm. in length, 0.31 mm. in breadth, and 0.14 mm. in thickness.

Remarks.—Several specimens of this species were sent to Miss Ruth Todd of the U. S. National Museum, Washington, D. C. who very kindly compared them with the holotypes of *S. chicoana* and *S. jarvisi*. On the basis of these specimens, she believed them closer to *S. jarvisi* because the holotype of *S. chicoana* has ". . . a sort of ragged peripheral keel and the wall is more coarsely arenaceous (and thus the sutures more obscure) than in *S. jarvisi* . . ." and also *S. jarvisi* has ". . . the position of the aperture within a deep re-entrant into the apertural face. . . ." Upon receiving this information, the writer examined many more specimens and found many with the more coarsely arenaceous wall, ragged peripheral keel and obscure sutures as well as some with apertures not having a deep re-entrant. Thus, there seems to be a continuous series of specimens ranging from those resembling the holotype of *S. chicoana* to those resembling the holotype of *S. jarvisi*, occurring together and apparently having the same stratigraphic range. The two have been considered the same species, therefore, and since *S. chicoana* has priority, *S. jarvisi* is placed as a junior synonym.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The holotype is from an Upper Cretaceous well core near Coalinga, California.

Family NODOSARIIDAE Schultze, 1854
Genus LENTICULINA Lamarck, 1804

Lenticulina LAMARCK, 1804, Paris Mus. National Hist. Nat., Ann., v. 5, p. 186; v. 8, 1806, pl. 62. (Described, no species named, but valid according to Rules of Nomenclature, Opinion 46.)
Robulus MONTFORT DE DENYS, 1808, Conch. Syst., v. 1, p. 215.
Lenticulina MARIE, 1941, Paris Mus. National Hist. Nat., Mém., n.s., v. 12, pt. 1, p. 95,258.

"Test planispiral, bilaterally symmetrical, completely coiled. Chambers numerous, embracing, profile triangular. Wall very finely perforate. Aperture circular or an elongate slit, surrounded or not by radiating

striae, situated at the apex of the apertural face."

Type species: *Lenticulina rotulata* (Lamarck) = *Lenticulites rotulata* Lamarck, 1804 (by subsequent designation, Cushman, 1927, Cushman Lab. Foram, Research, Contr., v. 3, p. 124).

Remarks.—The above description is from the French text after Marie, 1941 (see synonymy above). Considering the fact that the only apparent means of separating *Robulus* and *Lenticulina* is by the presence or absence of the apertural slit extending down into the apertural face, the writer has chosen to use the latter as emended by Marie, for the name has priority over the former. It is impossible with many specimens to distinguish this characteristic, and indeed, it appears to vary even within a single species. The author has observed specimens which, when broken apart, have the apertural slit present in the early chambers—or vice versa—but not in the adult chambers. This does not seem to be a gerontic tendency for an individual or for a single species, but, rather, the phenomenon appears to be the result of reabsorbtion of the apertural area by the organism in the ephebic stage. Even when recognizable, this feature is hardly of importance enough for generic distinctions; in fact, almost all authors fail to mention it in specific descriptions!

Marie also placed *Astacolus* (?) in synonymy, and various authors have since introduced typical species of *Astacolus* as *Lenticulina*. *Astacolus* may be easily distinguished by the compressed test and evolute nature of the later chambers that sweep back or nearly back to the involute portion; even when the inner ends of the chambers remain involute, the evolute nature of the outer ends will serve to place the species in the genus *Astacolus*.

Lenticulina californiensis Trujillo, sp. nov.
Pl. 45, figs. 7a,b

The shape of the test of *Lenticulina californiensis* is lenticular, closely coiled, and biumbonate with the umbo diameter about one-third that of the test. The periphery is smooth, and the edge is adorned with a very thin, easily broken keel that usually is not present on the last one or two chambers. There are ten–twelve chambers in the final whorl, increasing very gradually in size as added, and the last few tending to be somewhat evolute. Sutures are strongly curved, tangential, and limbate, with the initial ones indistinct and flush, later becoming raised, more distinct, and the final few prominently raised. The wall is calcareous, finely perforate, and smooth except for the raised sutures. The aperture is at the apex of the last septal face, produced, radiate, with about twelve radial teeth usually visible. The holotype measures 0.76 mm. in diameter, and 0.35 mm. in thickness.

Remarks.—This species is unique in the possession of the very fragile keel, distinct umbos, prominently raised final few sutures, and produced aperture. It somewhat resembles *L. velascoensis* White, from which it is distinguished by the opaque umbos that conceal the initial whorls, and by the character of the sutures. Although very distinctive, the species occurs too rarely to make a good marker, at least in the Redding area.

Unfigured paratypes.—UCLA no. 26603.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary to Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner, sec. 35, T32N, R2W, Shasta County, California. The species is found rarely in both Member IV, Coniacian, and Member VI, Santonian.

Lenticulina futabaensis (Asano)
Pl. 45, figs. 2a–2b

Robulus futabaensis Asano, 1950, Pacific Science, Honolulu, v. 4, no. 2, p. 159, pl. 1, fig. 12.

The shape of the test of *Lenticulina futabaensis* is closely coiled, moderately compressed, periphery acute or with a slight keel. There are seven to eight chambers in the adult whorl that are distinct, of uniform shape, and increase gradually in size. Sutures are distinct, gently curved, and become thick and raised toward the umbilical area. The wall is smooth. Aperture is radiate with a weak ventral slit. The hypotype measures 0.78 mm. in length, 0.55 mm. in breadth, and 0.24 mm. in thickness.

Remarks.—Most of the specimens of this study have one or two more chambers and

sides more nearly parallel than does the holotype; however, the character of the sutures and periphery seems identical and the differences are considered to be within the range of variation of the species.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The holotype is from a Senonian well core near Yokouchi, Fukushima Prefecture, Honshu Island, Japan.

LENTICULINA KANSASENSIS Morrow
Pl. 45, figs. 6a,b

Lenticulina kansasensis MORROW, 1934, Jour. Paleontology, v. 8, p. 189, pl. 30, fig. 23; LOETTERLE, 1937, Nebraska Geol. Survey, Bull. 12, ser. 2, p. 22, pl. 1, fig. 6; CUSHMAN, 1941, Cushman Lab. Foram. Research, Contr., v. 17, p. 64, pl. 16, fig. 8; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 56, pl. 18, fig. 15.

The shape of the test of *Lenticulina kansasensis* is involute, the sides are strongly convex, the thickness is almost half the diameter, with an even periphery and sharp edge. There are ten to twelve chambers in the final whorl. Sutures are limbate, curved, meeting the periphery obliquely, and elevated into narrow sharp ridges which die out before reaching the periphery and fuse at the center into a distinct boss. The wall is smooth except for the raised sutures. The aperture is elliptical and located at the apex of the apertural face. The hypotype measures 0.71 mm. in diameter, and 0.37 mm. in thickness.

Remarks.—The holotype was refigured by Cushman (1946), showing the last chamber broken and the apertural characteristics indiscernible. The specimens of this study show radiate apertures, and some, as the figured hypotype, have a slight keel on the early chambers.

Occurrence.—Studied specimens are from Member VI, Santonian. The holotype is from the basal Niobrara, Coniacian.

LENTICULINA MACRODISCA (Reuss)
Pl. 45, figs. 1a,b

Cristelleria (*Cristellaria*) *macrodisca* REUSS, 1863, K. Akad. Wiss. Wien, Math.-Naturw, Cl.,

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EXPLANATION OF PLATE 45

FIG. *1a,b—Lenticulina macrodisca* (Reuss). *1a*, side view; *1b*, edge view; both ×50. Hypotype: UCLA no. 26606; loc. no. 52.

2a,b—Lenticulina futabaensis (Asano). *2a*, side view; *2b*, edge view; both ×36. Hypotype: UCLA no. 26604; loc. no. 22.

3a,b—Lenticulina modesta (Bandy). *3a*, side view; *3b*, edge view; both ×36. Hypotype: UCLA no. 26607; loc. no. 22.

4a,b—Lenticulina warregoensis Crespin. *4a*, side view; *4b*, edge view; both ×28. Hypotype: UCLA no. 26609; loc. no. 62.

5a,b—Lenticulina pseudo-secans (Cushman). *5a*, side view; *5b*, edge view; both ×28. Hypotype: UCLA no. 26608; loc. no. 30.

6a,b—Lenticulina kansasensis Morrow. *6a*, side view; *6b*, edge view; both ×36. Hypotype: UCLA no. 26605; loc. no. 90.

7a,b—Lenticulina californiensis Trujillo, sp. nov. *7a*, side view; *7b*, edge view; both ×28. Holotype: UCLA no. 26602; loc. no. 90.

8a,b—Lingulina californiensis Trujillo, sp. nov. *8a*, side view; *8b*, terminal view; both ×68. Holotype: UCLA no. 26610; loc. no. 62.

9a,b—Lingulina lucillea Trujillo, sp. nov. *9a*, side view; *9b*, terminal view; both ×50. Holotype: UCLA no. 26612; loc. no. 90.

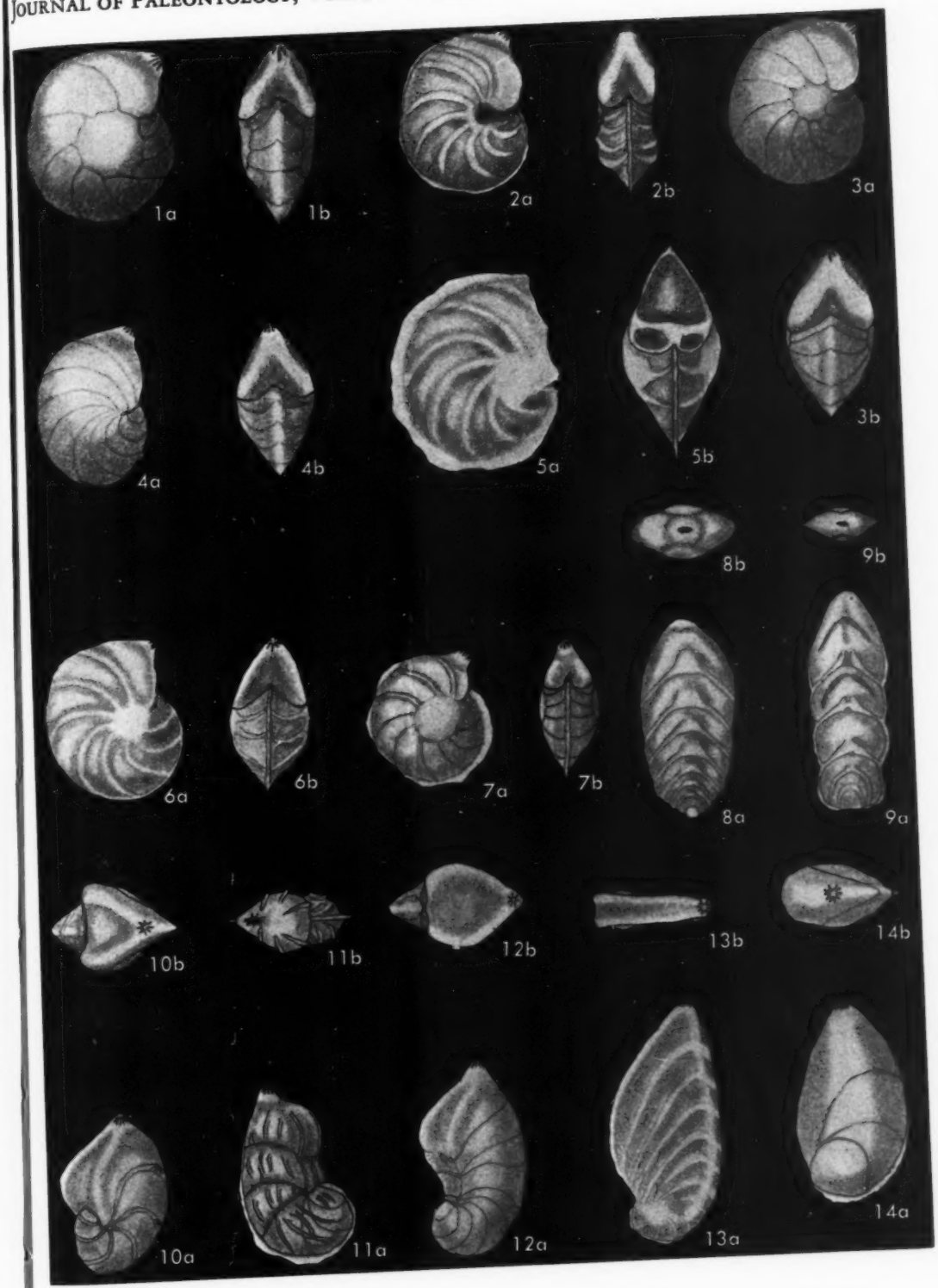
10a,b—Saracenaria cowcreekensis Trujillo, sp. nov. *10a*, oblique side view; *10b*, terminal view; both ×64. Holotype: UCLA no. 26614; loc. no. 64.

11a,b—Saracenaria tunesiana ten Dam & Sigal. *11a*, oblique side view; *11b*, terminal view; both ×32. Hypotype: UCLA no. 26617; loc. no. 81.

12a,b—Saracenaria triangularis d'Orbigny. *12a*, oblique side view; *12b*, terminal view; both ×28. Hypotype: UCLA no. 26616; loc. no. 90.

13a,b—Astacolus umbonatus (Loetterle). *13a*, side view; *13b*, terminal view; both ×55. Hypotype: UCLA no. 26621; loc. no. 90.

14a,b—Astacolus polandensis Trujillo, nom. nov. *14a*, side view; *14b*, terminal view; both ×50. Hypotype: UCLA no. 26619; loc. no. 62.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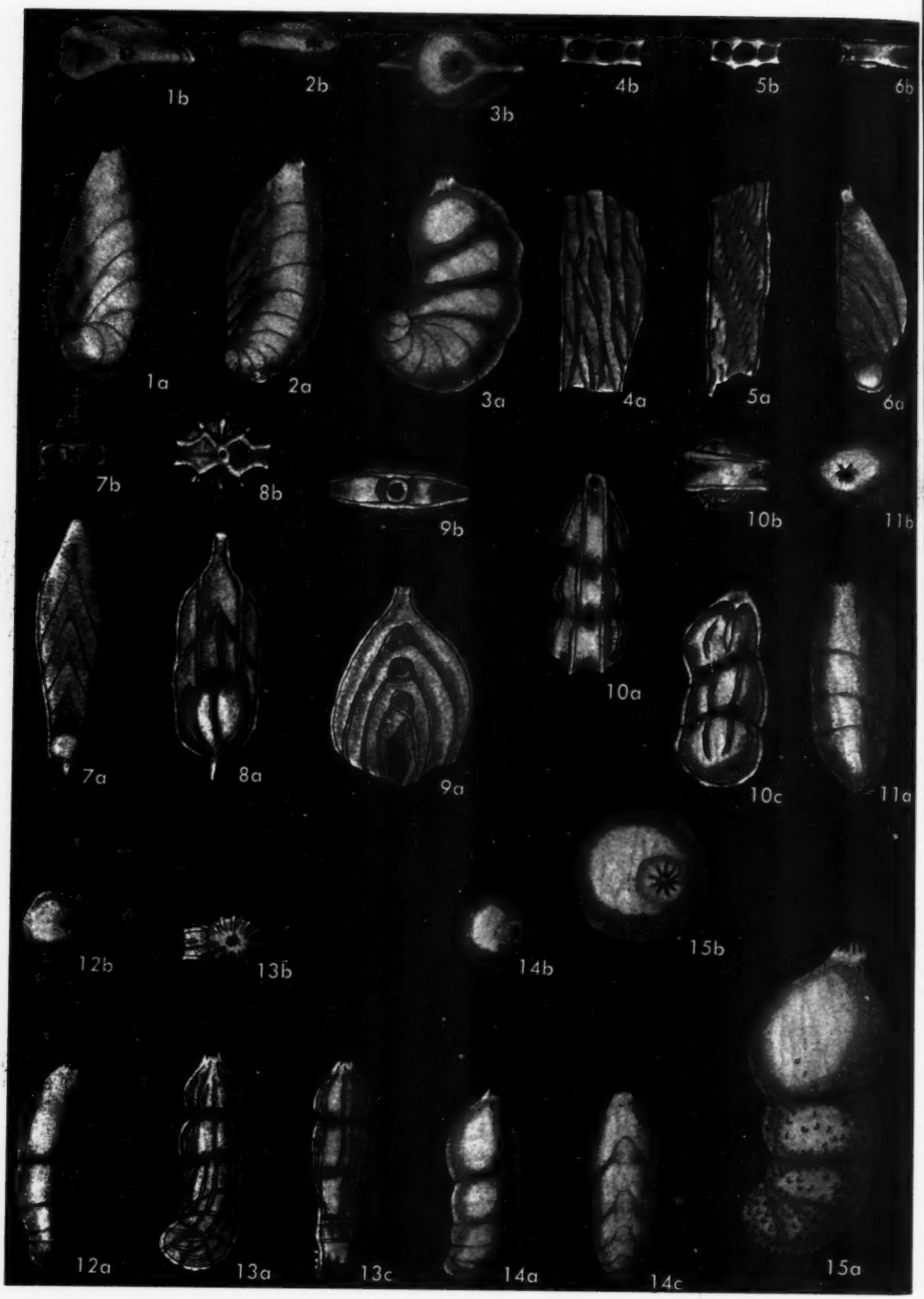
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Sitzber, Bd. 46, Abth. 1, p. 78, pl. 9, fig. 5; BERTHELIN, 1880, Soc. géol. France Mém., ser. 3, v. 1, no. 5, p. 48, pl. 3(26) figs. 6–11.
Lenticulina macrodisca WHITE, 1928, Jour. Paleontology, v. 2, p. 198, pl. 28, fig. 7.
Robulus macrodiscus CUSHMAN & JARVIS, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 23, pl. 7, fig. 3; CUSHMAN, 1936, Geol. Soc. America, Bull., v. 47, p. 416; ——, 1941, Cushman Lab. Foram. Research, Contr., v. 17, p. 60, pl. 15, fig. 9; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 54, pl. 17, fig. 14.

The shape of the test of *Lenticulina macrodisca* is round, very convex, edge sharply acute, and a very large umbo covering nearly half of the chambers. There are seven to eight curved, uninflated chambers in the final whorl, the last septal face being inverted-heart shaped, shallowly depressed, with both sides surrounded by a narrow, elevated border. The hypotype measures 0.53 mm. in diameter, and 0.24 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. It is reported from Mexico and Trinidad, and extensively in Europe. The holotype was from Germany, but no type horizon or locality was designated.

LENTICULINA MODESTA (Bandy)
Pl. 45, figs. 3a,b

Robulus modestus BANDY, 1951, Jour. Paleontology, v. 25, no. 4, p. 493, pl. 72, fig. 9.

The shape of the test of *Lenticulina modesta* is lenticular, closely coiled, biumbonate, with distinct umbonal areas of clear shell material that are flush with the surface. The periphery is smooth, and the edge is acute. There are seven to nine chambers, very gradually increasing in size as added, the last one or two tending to become evolute. Sutures are flush, tangential, slightly curved, and narrowly limbate. The wall is calcareous, finely perforate, and smooth. The aperture is at the outer edge of the last septal face, radiate, with about eight teeth and a narrow apertural extension downward into the septal face. The hypotype measures

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EXPLANATION OF PLATE 46

FIG. *1a,b—Astacolus polandensis* Trujillo, nom. nov. *1a*, side view; *1b*, terminal view; both ×50. Hypotype: UCLA no. 26620; loc. no. 62.
2a,b—Astacolus jarvisi (Cushman). *2a*, side view; *2b*, terminal view; both ×32. Hypotype: UCLA no. 26618; loc. no. 64.
3a,b—Vaginulinopsis reddingensis Trujillo, sp. nov. *3a*, side view; *3b*, terminal view; both ×32. Holotype: UCLA no. 26622; loc. no. 90.
4a,b—Planularia cf. *P. simondsi* (Carsey). *4a*, side view; *4b*, terminal view; both ×46. Hypotype: UCLA no. 26628; loc. no. 43.
5a,b—Planularia eriksdalensis (Brotzen). *5a*, side view; *5b*, terminal view; both ×32. Hypotype: UCLA no. 26626; loc. no. 43.
6a,b—Planularia kochii (Roemer). *6a*, side view; *6b*, terminal view; both ×32. Hypotype: UCLA no. 26627; loc. no. 20.
7a,b—Frondicularia chapmani Perner. *7a*, side view; *7b*, terminal view; both ×32. Hypotype: UCLA no. 26630; loc. no. 20.
8a,b—Frondicularia durrelli Trujillo, sp. nov. *8a*, side view; *8b*, terminal view; both ×55. Holotype: UCLA no. 26631; loc. no. 90.
9a,b—Kyphopyxa christneri (Carsey). *9a*, side view; *9b*, terminal view; both ×52. Hypotype: UCLA no. 26629; loc. no. 90.
10a–c—Vaginulina cf. *V. delicatocostata* Bartenstein & Brand. *10a*, ventral view; *10b*, terminal view; *10c*, side view; all ×55. Hypotype: UCLA no. 26624; loc. no. 39.
11a,b—Vaginulina modesta (Reuss). *11a*, side view; *11b*, terminal view; both ×46. Hypotype: UCLA no. 26625; loc. no. 59.
12a,b—Marginulina obliquinodus Bandy. *12a*, side view; *12b*, terminal view; both ×52. Hypotype: UCLA no. 26637; loc. no. 47.
13a–c—Marginulinopsis praetschoppi Trujillo, sp. nov. *13a*, side view; *13b*, terminal view; *13c*, ventral view; all ×32. Holotype: UCLA no. 26633; loc. no. 90.
14a–c—Marginulina troedssoni Brotzen. *14a*, side view; *14b*, terminal view; *14c*, dorsal view; all ×52. Hypotype: UCLA no. 26638; loc. no. 20.
15a,b—Marginulina loisana Trujillo, sp. nov. *15a*, side view; *15b*, terminal view; both ×52. Holotype: UCLA no. 26635; loc. no. 90.

0.79 mm. in length, 0.63 mm. in breadth, and 0.44 mm. in thickness.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The holotype is from the Campanian near Carlsbad, San Diego County, California.

LENTICULINA PSEUDO-SECANS
(Cushman)
Pl. 45, figs. 5a,b

Robulus pseudo-secans CUSHMAN, 1938, Cushman Lab. Foram. Research, Contr., v. 14, p. 32, pl. 5, fig. 3; ——, 1941, *idem*, v. 17, p. 59, pl. 15, fig. 7; ——, 1944, *idem*, v. 20, p. 85; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 53, pl. 17, figs. 11–13; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 81, pl. 8, fig. 8.

The shape of the test of *Lenticulina pseudo-secans* is strongly umbonate thence thinning to the periphery which is acute and keeled. There are eight to nine distinct, uninflated chambers in the adult coil, and are of uniform shape, increasing gradually in size as added. The sutures are distinct, strongly limbate and raised, confluent with the highly rounded umbo, inner portion tangential, nearly straight, thence increasingly curved toward the periphery. Wall is smooth, except for the raised portions. The aperture is radiate, at the peripheral angle. The hypotype measures 1.12 mm. in diameter, and 0.59 mm. in thickness.

Remarks.—Only broken specimens were found in this study that are apparently referable to this species.

Occurrence.—Studied specimens are from Member II, Middle Turonian, and Member IV, Coniacian. The species is reported from the Gulf Coast Santonian, Campanian, and Maestrichtian. The holotype is from the middle part of the Selma chalk, Campanian, Hardin County, Tennessee.

LENTICULINA WARREGOENSIS Crespin
Pl. 45, figs. 4a–4b

Lenticulina warregoensis CRESPIN, 1944, Royal Soc. New South Wales, Jour. Proc., v. 78 (1946), pts. 1,2 (1945), art. 3, p. 21.

The shape of the test of *Lenticulina warregoensis* is slightly elongate, medium sized, oval, with the peripheral outline evenly curved but faintly angular in last chamber, and the edge acute. There are ten chambers in the final whorl, with the early ones involute, but rapidly becoming evolute and increasing in size. Sutures are curved, especially in the early portion where they are close together. The wall is translucent and smooth. Aperture is radiate and protruding. The hypotype measures 0.91 mm. in length, 0.70 mm. in breadth, and 0.47 mm. in thickness.

Remarks.—The illustration of the holotype is very poor, but from the general outline and description, the Redding specimens seem to belong to this species. Many of the specimens are slightly less convex and more involute than the hypotype.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The holotype is from Lower Cretaceous rocks near the Warrego River and near Ellaville, New South Wales, Australia.

Genus LINGULINA d'Orbigny, 1826
LINGULINA CALIFORNIENSIS
Trujillo, sp. nov.
Pl. 45, figs. 8a,b

The shape of the test of *Lingulina californiensis* is elongate, compressed, about twice longer than broad, increasing rapidly in breadth initially, but very slowly in the final three-fourths, with the greatest breadth and thickness at the base of the final chamber. The periphery is very slightly lobulate and the edge is sharply rounded or acute, but not keeled. There are eight to ten distinct chambers in the adult, arranged in a linear series, only slightly inflated, and strongly overlapping following the tiny spherical proloculum. They increase gradually in height as added, with the breadth two to three times the height except the last chamber, which is much higher, while the basal portion of each bulges out and is somewhat transparent where the apertural end of the previous chamber is overlapped. Sutures are distinct, slightly depressed, limbate, with the central part blending in with the elevated part of the chamber and are semicircular or arcuate in the initial portion, becoming sub-chevron shaped in the adult portion. The wall is calcareous, finely perforate, and smooth. Aperture is terminal, small, elliptical. The holotype measures 0.49 mm.

in length, 0.24 mm. in greatest breadth, and 0.12 mm. in greatest thickness.

Remarks.—Distinguishing features of this species are the sharply rounded or acute edge, the raised central portion of the chambers, and the sub-chevron shaped sutures of the adult portion, the upper central part of which blends in with the raised area of the chamber.

The most similarity is with *L. taylorana* Cushman, which differs chiefly in possessing thin flanges at the basal angle of each chamber, and apparently lacks the distinctive raised central area on each chamber. *L. minima* (Franke) (*Frondicularia minima* Franke, 1913, a junior synonym of *Frondicularia minima* Kubler & Zwingli, 1866) is also apparently quite similar, but differs in having a more lobulate periphery and more depressed sutures, as well as in lacking the elevated portion on each chamber. *L. lucillea* (a new species also discussed in the present paper) differs in being less broad, more elongate, sides more parallel, apertural end more pointed, and the edge keeled.

The specimens are exceedingly well preserved, but occur so rarely that the value of the species as a Coniacian index is slight.

Additional paratypes.—UCLA no. 26611.

Occurrence.—The holotype is from Member IV, Coniacian, locality 62, on the north bank of Clover Creek, about 900 feet south and 1200 feet west of the NE corner, sec. 32, T32N, R2W, Shasta County, California. The species is apparently restricted to Member IV, from which all of the studied specimens came.

LINGULINA LUCILLEA Trujillo,
sp. nov. Pl. 45,
figs. 9a,b

The shape of the test of *Lingulina lucillea* is elongate, very compressed, about three to four times longer than broad, sides parallel almost from the initial end which is blunt and only slightly rounded, while the apertural end is pointed. The periphery is slightly lobulate to smooth, and the edge is ornamented with a distinct, narrow keel that is easily broken and often extends only onto the penultimate chamber and never reaches the aperture. Chambers are distinct, slightly inflated, lozenge-shaped in transverse section, about as high as broad in the middle portion of the test, the last chamber much higher, and strongly overlapping. There are usually six to eight in the adult, with the basal central area of each chamber slightly raised, and transparent such that the entosolenian tube extending from the aperture of the preceding chamber is often visible. Sutures are limbate, depressed, the upper central portion of each blending with the raised area of the chamber, and arcuate in shape except the last one or two which tend to become chevron-like. The wall is calcareous, finely perforate and smooth except for the small raised area of each chamber, and some specimens have a narrow, shallowly depressed groove on the upper part of the final one or two chambers that nearly parallels the suture line. The aperture is terminal, small, and elliptical. The hypotype measures 0.69 mm. in length, 0.27 mm. in greatest breadth, and 0.09 mm. in greatest thickness.

Remarks.—The keeled edge, parallel sides, blunt initial end, pointed apertural end, ratio of breadth to width, and when present, the distinctive groove on the chambers, should serve to distinguish this from all other species.

The above criteria, especially the keeled edge, will set this species apart from *L. californiensis* (a new species also described in the present paper) which it most closely resembles.

Preservation of specimens is good except that the fragile keel is often broken.

The specific name is in honor of Mrs. Lucille Porter, University of California, Los Angeles.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary to Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner, sec. 35, T32N, R2W, Shasta County, California. The species occurs rarely in both Member IV, Coniacian, and Member VI, Santonian.

Genus SARACENARIA Defrance, 1824
SARACENARIA COWCREEKENSIS
Trujillo, sp. nov.
Pl. 45, figs. 10a,b

The shape of the test of *Saracenaria cowcreekensis* is involute, closely coiled, the outer portion tending toward evoluteness, and triangular in transverse section. The

periphery is smooth, and the edge is acute, with a tendency to be keeled in the early portion. Chambers are distinct, closely appressed, increasing gradually in size as added except the final chamber which is proportionately higher, more pointed, and more overlapping. There are usually six to eight chambers in the microspheric generation, and seldom more than three following the bulbous proloculum in the megalospheric generation. Sutures are distinct, limbate, smooth or very slightly raised, strongly curved, and the radial teeth of the penultimate and preceding one to two apertures often visible near the peripheral extremity. The wall is calcareous, finely perforate, smooth, and often quite vitreous looking. The aperture is terminal, at the apex of the last septal face which is concave, and radiate with eight to ten radial teeth. The holotype measures 0.38 mm. in length, 0.32 mm. in breadth, and 0.23 mm. in thickness.

Remarks.—The species is set apart from all others by the involute test with outer margin tending to become evolute, the distinctive limbate sutures, the very acute edge, and the unique ultimate chamber with pointed apex and concave septal face.

The megalospheric specimens usually have a slight keel on the initial portion, whereas the microspheric forms usually do not, although the distinction is sometimes difficult as the edge is so acute.

Additional paratypes.—UCLA no. 26615.

Occurrence.—The holotype is from Member IV, Coniacian, locality 64, on the south bank of Clover Creek, tributary of Cow Creek, about 700 feet south and 900 feet west of the NE corner sec. 32, T32N, R2W, Shasta County, California. Studied specimens are from both Member IV, Coniacian, and Member VI, Santonian.

SARACENARIA TRIANGULARIS (d'Orbigny)
Pl. 45, figs. 12a-12b

Cristellaria triangularis D'ORBIGNY, 1840, Soc. Géol. France, Mém., v. 4, no. 1, p. 27, pl. 2, figs. 21,22; REUSS, 1854, K. Akad. Wiss. Wien, Math-Naturw. Cl., Denkschr., Bd. 7, p. 68; EGGER, 1899, K. Bayer Akad. Wiss., Math.-naturh. Abt., Abh., kl. 2, v. 21, p. 117, pl. 12, figs. 5,6.

Saracenaria triangularis CUSHMAN & CHURCH, 1929, Calif. Acad. Science Proc., ser. 4, v. 18, p. 505, pl. 37, figs. 13,14; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 58, pl. 28, figs. 1–3 (see this reference for complete synonomy to 1946); ——, 1949, Maryland Dept. Geology, Mines and Water Resources, Bull. 2, p. 253, pl. 22, fig. 16; BANDY, 1951, Jour. Paleontology, v. 25, no. 4, p. 494, pl. 72, fig. 11, FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 83, pl. 8, fig. 28.

Astacolus jarvisi BROTZEN (in part), 1936, Sveriges geol. undersökning, ser, C, no. 396, p. 56, pl. 3, figs. 6a,c (not 5a,b, 7a,b).

The shape of the test of *Saracenaria triangularis* is fairly large, early portion completely coiled, later somewhat uncoiled, with triangular transverse section and acute dorsal edge. Chambers are distinct and numerous. The sutures are distinct, flush, and curved. Wall is calcareous, finely perforate, smooth. The aperture is terminal, on the dorsal edge of the last septal face, which is convex with somewhat projecting borders, and radiate with about twelve radial teeth. The hypotype measures 1.02 mm. in length, 0.73 mm. in breadth, and 0.45 mm. in greatest thickness.

Remarks.—The large evolute specimens as the one figured are seemingly identical to the holotype and occur only in Member VI, Santonian, while the less evolute specimens as are commonly reported occur in both Member IV, Coniacian, and Member VI.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species has been reported from the Campanian of the Carlsbad area, San Diego County, California, throughout the Senonian and Maestrichtian of the Gulf Coast, in Maryland, and extensively in Europe. The holotype is from the Cretaceous white chalk at Sens, department de l'Yonne, France.

SARACENARIA TUNESIANA ten Dam & Sigal
Pl. 45, figs. 11a,b

Saracenaria tunesiana TEN DAM & SIGAL, 1950, Cushman Found. Foram. Research, Contr., v. 1, p. 36, pl. 2, fig. 21.

The shape of the test of *Saracenaria tunesiana* is relatively short, triangular in section, about twice as long as broad, initial coil comprising about one-third of the entire test. The dorsal periphery is strongly curved, with a sharp and narrow keel, while the ventral face is ovoid, taper-

ing at both ends and laterally bordered by a raised limbate rim. There are five chambers in the initial coil, increasing in height as added, followed by four to five uniserial chambers which increase only slightly in size as added, with the last formed chamber slightly inflated on the ventral face. Sutures are distinct, flush with the surface in the initial portion, and slightly depressed and gently curved in the uniserial part. The wall is calcareous, perforate, surface ornamented by several sharp, narrow, slightly elevated and limbate costae that are curved and almost parallel with the dorsal periphery. The aperture is terminal, radiate. The hypotype measures 0.87 mm. in length, 0.54 mm. in breadth, and 0.27 mm. in thickness.

Remarks.—On the basis of the holotype illustration and many of the specimens of this study, the species would be more appropriately placed in the genus *Vaginulinopsis*, for the triangularity is due primarily to the two widely spaced ventral costae. Within the same stratigraphic horizon, however, there is a great degree of variation from specimens with ovoid cross sections and barely discernible discontinuous costae to those with perfectly triangular cross sections and extremely coarse continuous costae. The hypotype is an intermediate form.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian, but the species is more abundant in Member VI.

Genus ASTACOLUS Denys de Montfort, 1808

ASTACOLUS JARVISI (Cushman)

Pl. 46, figs. 2a,b

Marginulina jarvisi CUSHMAN, 1938, Cushman Lab. Foram. Research, Contr., v. 14, p. 35, pl. 5, figs. 17,18; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, p. 969 (chart); CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 63, pl. 22, figs. 18–20.

Cristellaria grata CUSHMAN, 1926, Amer. Assoc. Petroleum Geologists, Bull., v. 10, p. 598, pl. 19, fig. 1.

Lenticulina grata CUSHMAN & JARVIS, 1928, Cushman Lab. Foram. Research, Contr., v. 4, p. 96, pl. 14, fig. 3.

Marginulina grata CUSHMAN & JARVIS, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 25, pl. 7, fig. 7; pl. 8, fig. 3.

Marginulina schloenbachi CUSHMAN & JARVIS, 1932, *idem*, p. 26, pl. 8, fig. 5.

(*non*) *Astacolus jarvisi* BROTZEN, 1936, Sverges geol. undersökning, ser. C, no. 396, p. 56, pl. 3, figs. 5–7.

The shape of the test of *Astacolus jarvisi* is compressed and elongate with the earliest portion coiled, later uncoiling, with a slightly concave ventral margin, a convex dorsal margin, and a rounded periphery. The chambers are distinct, rather few, and the earliest four to six are coiled, the remainder are uncoiled and not inflated. The sutures are distinct, slightly limbate, not raised, and somewhat curved. The wall is smooth. Aperture is at the peripheral angle, radiate. The hypotype measures 1.11 mm. in length, 0.52 mm. in breadth, and 0.23 mm. in thickness.

Remarks.—*Astacolus jarvisi* Brotzen, 1936 (see synonymy) should be referred to *Saracenaria jarvisi* (Brotzen) at it is distinctly triangular in transverse section. Bandy (1951, p. 494) included the holotype in the synonymy of *Saracenaria triangularis* (d'Orbigny). In this paper the paratype is also placed in synonymy with *S. triangularis*. According to Dr. A. Myra Keen of Stanford University (personal communication), in a situation such as this, homonymy does not exist according to present rules of zoological nomnclature, and especially as clarified by the new draft edition.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species is found in the Holz shale. Upper Turonian-Lower Coniacian of the Santa Ana Mountains, California, the Upper Cretaceous of the Great Valley, California, in the Paleocene Velasco shale of the Tampico Embayment, Mexico, and somewhat similar specimens occur in the upper part of the Navarro (Maestrichtian) of Texas (Cushman, 1946, p. 63). The holotype is from the Lizard Springs Formation, Paleocene-Lower Eocene, near Guayaguayare, Trinidad, British West Indies.

ASTACOLUS POLANDENSIS Trujillo, nom. nov.

Pl. 45, figs. 14a,b; Pl. 46, figs. 1a,b

Cristellaria simplex DUNIKOWSKI, 1879, Kosmos, Lvov, v. 4, p. 126, pl. (?), fig. 19.

(*non*) *Cristellaria simplex* D'ORBIGNY, 1846, Gide et Comp., Paris, France, p. 85, pl. 3, figs. 26–29.

(*non*) *Cristellaria simplex* TERQUEM, 1864, Acad.

Imp. Metz, Mém., année 44 (1862–1863), ser. 2, année 11, pt. 2, p. 413, pl. 9, fig. 15.
(*non*) *Cristellaria simplex* KÜBLER & ZWINGLI, 1866, Winterthur, Burgersbibl., Neujahrsbl., Winterthur, Schweiz, p. 10, pl. 1, fig. 28.

The shape of the test of *Astacolus polandensis* is strongly compressed, and elongate elliptical in outline. There are seven to eight very closely appressed chambers arranged in a spiral series. The sutures all start from one point on the circumference of the ellipse and diverge from that point in radiating arcs toward the opposite periphery of the test. The wall is porcelaneous-glassy, completely smooth on the surface. The aperture is circular, situated on the produced, conically pointed apex of the last chamber. The hypotype measurements are: Pl. 3, fig 14—0.63 mm. in length, 0.38 mm. in breadth, 0.18 mm. in thickness; Pl. 4, fig. 1—0.72 mm. in length, 0.41 mm. in breadth, and 0.24 mm. in thickness.

Remarks.—As may be seen from the synonymy, *C. simplex* Dunikowski is a junior homonym of *C. simplex* d'Orbigny, as are two other species. The species is therefore in need of a new name.

The specimens of this study, although somewhat variable in the amount of involuteness, all have the same outline, number of chambers, pointed last chamber, and the glassy smooth wall of the holotype. Those specimens depicted by figures 14a–14b, Plate 45, having a small keel initially are considered to be the megalospheric generation of the species. In other respects the specimens such as this do not differ from the typical microspheric form, and inasmuch as they have the same stratigraphic range and occur together, this interpretation seems justified.

The holotype of *Cristellaria simplex* Dunikowski (see synonymy above) is deposited in the collections of the Geological Museum of the Technical School of Lvov, Poland.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The holotype was collected from the Senonian near Pelczynski's pond in Lvov, eastern Poland.

ASTACOLUS UMBONATUS (Loetterle)
Pl. 45, figs. 13a,b

Planularia umbonata LOETTERLE, 1937, Nebraska Geol. Survey, Bull., ser. 2, no. 12, p. 23, pl. 2, fig. 2.

The shape of the test of *Astacolus umbonatus* is elongate, tending to uncoil, much compressed, with sides almost parallel in edge view except for the early tightly coiled portion which is broadly umbonate. The outer periphery is broadly truncate, thickened and smooth, with a narrow keel in the early stage. Chambers are numerous, much wider than high, of about the same height throughout. Sutures are limbate and elevated, strongly oblique in the later portion and variable thickened near the periphery into raised masses which are visible as knob-like processes in edge view. Aperture is radiate, at the peripheral angle. The hypotype measures 0.68 mm. in length, 0.34 mm. in breadth, and 0.09 mm. in thickness.

Remarks.—Most of the specimens of this study are somewhat more compressed with less prominent umbos and raised peripheral suture knobs than the holotype, but these features are variable.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The holotype is from the Santonian Smoky Hill chalk beds of the Niobrara Formation on the bluffs of the Republican River near Red Cloud, Nebraska. Loetterle also reports the species from Fort Hays limestone, of Coniacian age, near St. James, Nebraska.

Genus VAGINULINOPSIS Silvestri, 1904
VAGINULINOPSIS REDDINGENSIS
Trujillo, sp. nov.
Pl. 46, figs. 3a,b

The shape of the test of *Vaginulinopsis reddingensis* is robust, compressed, subovoid in adult transverse section, with the early portion completely coiled and the later portion uncoiling. The periphery is smooth initially, slightly lobulate in the adult portion, with the dorsal edge acute, especially in the early part, and the ventral edge rounded. Chambers are distinct, low, increasing very slowly in height, the last one higher and less broad, the last few tending to be inflated, appressed, with usually about seven in the coil and three to four in the uncoiled part. Sutures are limbate, strongly curved and flush initially, but in the adult portion becoming depressed, straight, transverse, and nearly parallel. The wall is calcareous, finely perforate, and smooth. Aperture is terminal, at or near the dorsal pe-

ripheral angle, strongly produced and radiate, with about twelve radial teeth. The holotype measures 1.04 mm. in length, 0.68 mm. in greatest breadth, and 0.40 mm. in greatest thickness.

Remarks.—The robust, evolute character of the test, strongly curved limbate initial sutures that become straightened and depressed in the adult, acute dorsal edge, high ultimate chamber and produced aperture make this species unique.

Some of the juvenile specimens would seem to belong to the genus *Astacolus;* however, the later chambers of the adult become normal to the dorsal edge, do not reach toward the early portion, and thus properly belong in the genus *Vaginulinopsis.*

Very few samples yielded this distinctive species, making it of negligible importance as an index fossil in the area of this study.

Additional paratypes—UCLA no. 26623.

Occurrence.—The species was found only in Member VI, Santonian, the holotype being from locality 90, on the south bank of gully tributary to Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner sec. 35, T32N, R2W, east of the city of Redding, Shasta County, California.

Genus VAGINULINA d'Orbigny, 1826

VAGINULINA cf. V. DELICATOCOSTATA Bartenstein & Brand

Pl. 45, figs. 10a,c

Vaginulina riedeli delicatocostata BARTENSTEIN & BRAND, 1952, Jour. Paleontology, v. 26, no. 6, p. 981.

Vaginulina rideli paucicostata BARTENSTEIN & BRAND (*non V. paucicostata* Reuss), 1951, Senckenbergiana Naturf. Ges., Abh., Frankfurt on Main, no. 485, p. 295, pl. 7, p. 166,167.

The shape of the test of *Vaginulina delicatocostata* is elongate and robust, almost square transverse section with the ventral edge somewhat wider than the dorsal edge. The initial chamber is large, spherical, lower end rounded, with the following chambers only slightly increasing in size, almost as high as broad, only the last one somewhat higher. Sutures are slightly depressed, partially with a narrow border. The wall is ornamented with distinct keels on the corners, longitudinal costae on the side, irregularly arranged on the ventral edge and occasionally developed only on one side. Aperture is terminal, produced, at the dorsal edge of the apex of the last chamber. The hypotype measures 0.56 mm. in length, 0.24 mm. in breadth, and 0.22 mm. in thickness.

Remarks.—Most of the limited number of specimens found were broken and are only tentatively referred to this species inasmuch as the costae are apparently absent on the ventral edge.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype is from a well near Nordhorn, Hannover, Germany, in rocks of Upper Valanginian age.

VAGINULINA MODESTA (Reuss)

Pl. 46, figs. 11a,b

Marginulina modesta REUSS, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber, v. 40, p. 207, pl. 7, fig. 5.

The shape of the test of *Vaginulina modesta* is elongate, nearly straight, the lower part very slightly curved and compressed, with the upper end obliquely pointed and the lower dorsal edge acute. There are seven to eight oval shaped chambers. Sutures are distinct and slightly curved. The wall is smooth and glassy. Aperture is produced, radiate, at the dorsal extremity of the last septal face. The hypotype measures 0.72 mm. in length, 0.32 mm. in breadth, 0.23 mm. in thickness.

Remarks.—Only juvenile specimens were found unbroken, and these have many fewer chambers; however, the broken adult specimens have more chambers and the last few tend to be somewhat inflated as the holotype illustration shows.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The holotype is from the Lower Senonian of Westphalia, Germany.

Genus PLANULARIA Defrance, 1824

Planularia DEFRANCE, 1824, Dict. Sci. Nat., v. 32, p. 178.

Citharina D'ORBIGNY, 1839, Hist. Phys. Pol. Nat. Cuba, Foram., p. xxxvii.

Citharina MARIE, 1938, Soc. Geol. France, Bull., ser. 5, v. 8, p. 93.

The shape of the test of *Planularia* is elongate, flattened, subtriangular in side view, with the early part curved but not making one volution and the later portion evolute. Chambers are numerous, increasing very rapidly in breadth as added. Sutures

are oblique and nearly parallel. The wall is calcareous, finely perforate, and with or without longitudinal costae. The aperture is terminal, near the dorsal edge, and radiate.

Type species: *Planularia auris* (Defrance) = *Peneroplis auris* Defrance, 1824 (monotypic).

Remarks.—Many species belonging to this genus are often mistakenly referred to the genera *Vaginulina* and/or *Citharina*. *Planularia* differs from *Vaginulina* primarily by the flat subtriangular test resulting from the rapid increase in breadth as added. *Citharina* is a junior homonym. The emendation by Marie (1938, see synonymy above) has not changed the situation although since then several authors have considered it valid, evidently on that basis. His distinction of *Citharina* from *Planularia* is that ". . . the younger chambers are not in a spiral but rectilinear. . . ," and it is also distinguished ". . . by a straight dorsal edge and a simple radiate aperture, without a medial slit." (from the French text of Marie). The type species of *Planularia* does not show, nor does the description state, that the early chambers are spirally arranged; to the contrary, the initial portion is curved but not at all coiled. The type species of *Citharina* is *Vaginulina costulata* Roemer, 1842 (following the Rules of Zoological Nomenclature, Opinion 46), and not *Vaginulina* (*Citharina*) *strigillata* Reuss, 1846, as given by Loeblich & Tappan (1949, Jour. Paleontology, V. 23, p. 259). The initial portion of the holotype is broken, but there is no reason to assume that the earliest portion is not curved to some degree as is the case with every species that has been referred to *Citharina* to date. Furthermore, the evolute nature of *Planularia*

EXPLANATION OF PLATE 47

FIG. *1a,b*—*Rectoglandulina pygmaea* (Reuss). *1a*, side view; *1b*, terminal view; both ×53. Hypotype: UCLA no. 26640; loc. no. 90.

2a,b—*Rectoglandulina mutabilis* (Reuss). *2a*, side view; *2b*, terminal view; both ×36. Hypotype: UCLA no. 26639; loc. no. 90.

3a,b—*Dentalina catenula* Reuss. *3a*, side view; *3b*, terminal view; both ×32. Hypotype: UCLA no. 26643; loc. no. 45.

4a,b—*Dentalina coalvillensis* Peterson. *4a*, side view; *4b*, terminal view; both ×32. Hypotype: UCLA no. 26644; loc. no. 29.

5a,b—*Dentalina* cf. *D. megalopolitana* Reuss. *5a*, side view; *5b*, terminal view; both ×32. Hypotype: UCLA no. 26645; loc. no. 43.

6a,b—*Dentalina peracuta* (Reuss). *6a*, side view; *6b*, terminal view; both ×32. Hypotype: UCLA no. 26646; loc. no. 61.

7a,b—*Nodosaria spinifera* Cushman & Campbell. *7a*, side view; *7b*, terminal view; both ×55. Hypotype: UCLA no. 26649; loc. no. 44.

8a,b—*Nodosaria tenuicosta* Reuss. *8a*, side view; *8b*, terminal view; both ×36. Hypotype: UCLA no. 26650; loc. no. 90.

9a,b—*Dentalina angusticostata* Cushman. *9a*, side view; *9b*, terminal view; both ×32. Hypotype: UCLA no. 26641; loc. no. 67.

10a,b—*Nodosaria aspera* Reuss. *10a*, side view; *10b*, terminal view; both ×55. Hypotype: UCLA no. 26647; loc. no. 39.

11a,b—*Dentalina bighornensis* (Young). *11a*, side view; *11b*, terminal view; both ×32. Hypotype: UCLA no. 26642; loc. no. 20.

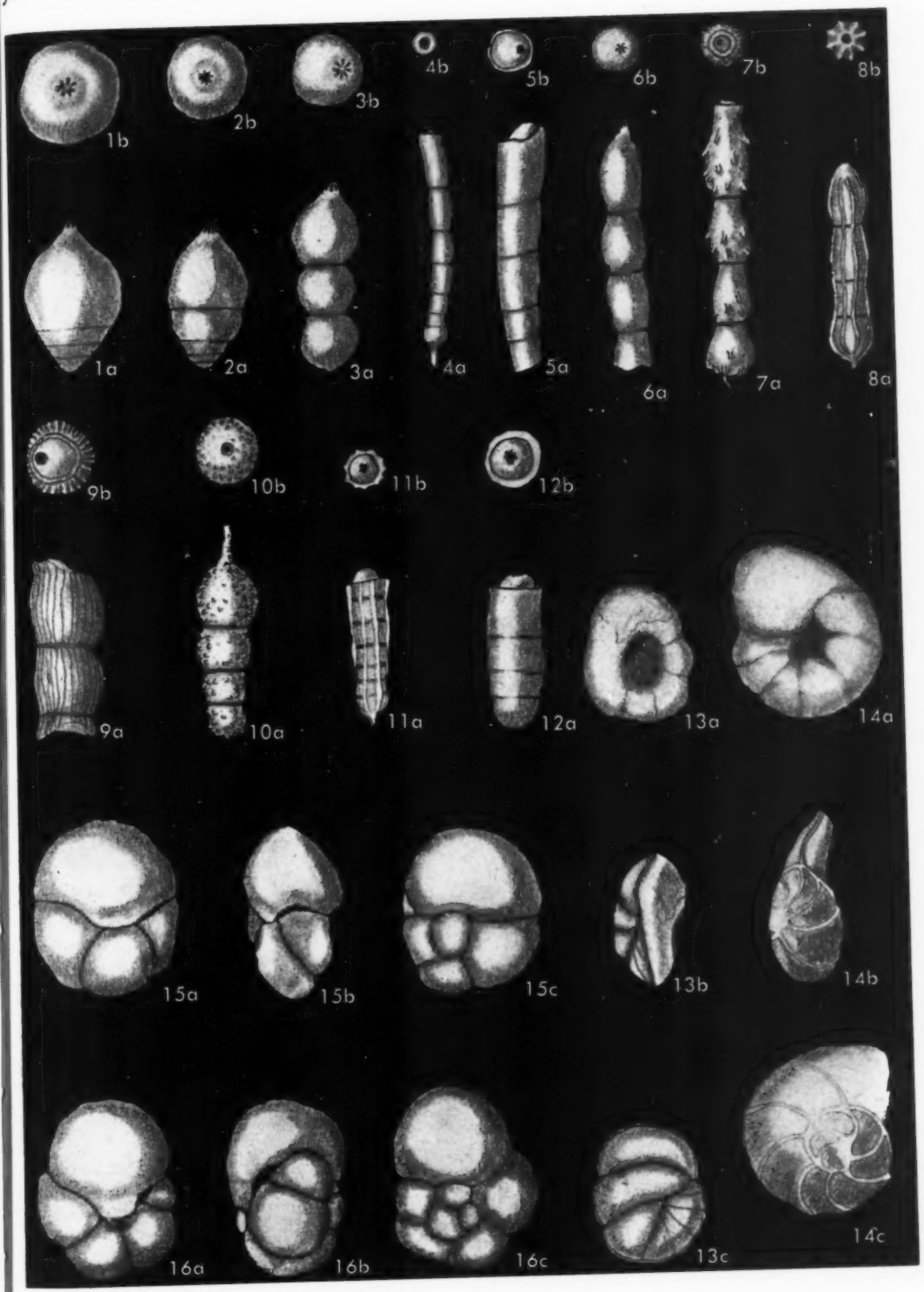
12a,b—*Nodosaria orthophragma* Egger. *12a*, side view; *12b*, terminal view; both ×32. Hypotype: UCLA no. 26648; loc. no. 44.

13a–c—*Lamarckina reedana* Trujillo, sp. nov. *13a*, umbilical view; *13b*, edge view; *13c*, spiral view; all ×55. Holotype: UCLA no. 26670; loc. no. 20.

14a–c—*Lamarckina stormi* Brotzen. *14a*, umbilical view; *14b*, edge view; *14c*, spiral view; all ×55. Hypotype: UCLA no. 26672; loc. no. 20.

15a–c—*Quadrimorphina allomorphinoides* (Reuss). *15a*, umbilical view; *15b*, edge view; *15c*, spiral view; all ×48. Hypotype: UCLA no. 26653; loc. no. 90.

16a–c—*Valvulineria marianosi* Trujillo, sp. nov. *16a*, umbilical view; *16b*, edge view; *16c*, spiral view; all ×55. Holotype: UCLA no. 26651; loc. no. 90.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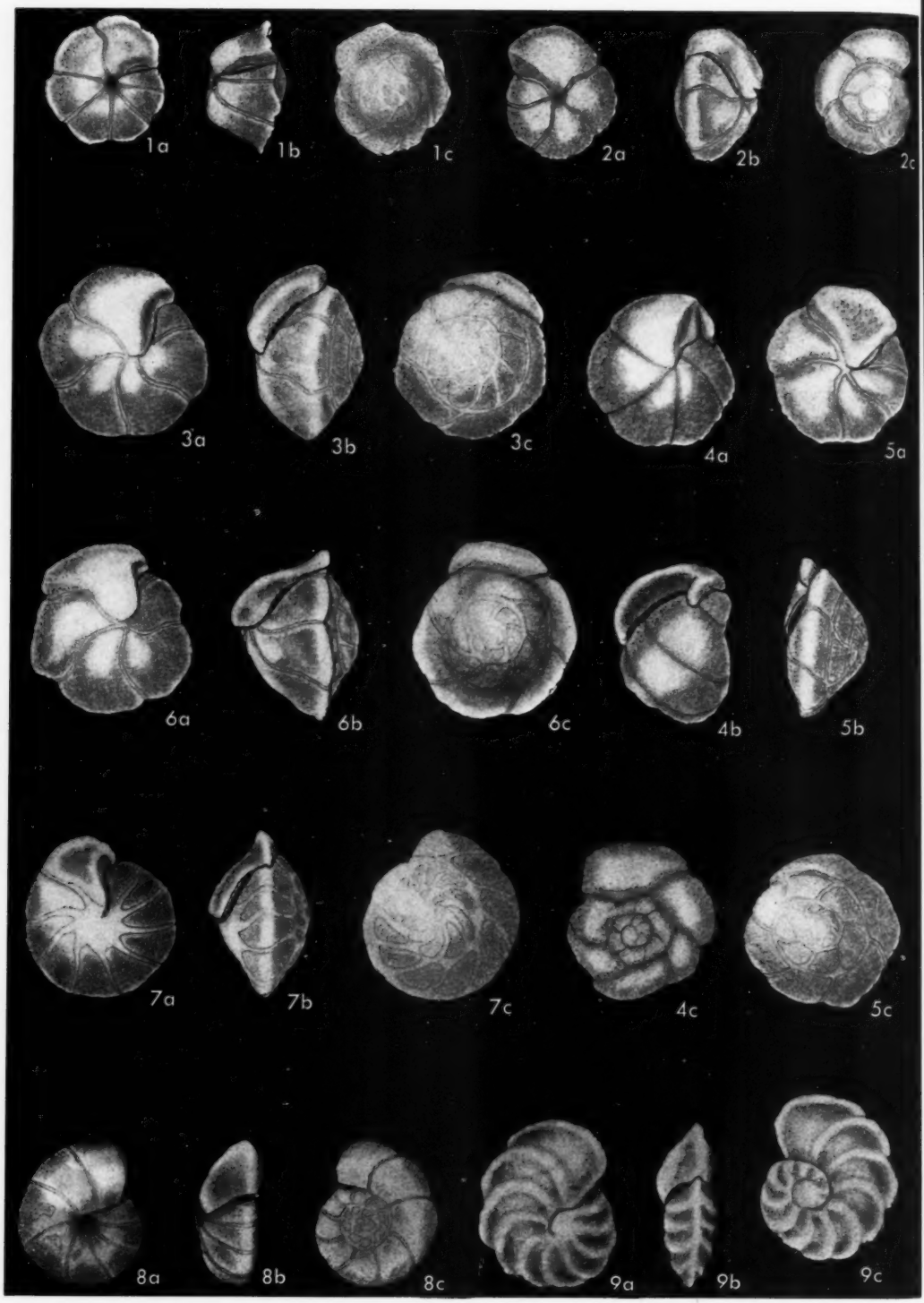
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9b
9c

would include a straight dorsal edge, and as for the aperture, it is certainly not restricted to radiate apertures with medial slits. Thus, with no generic characteristic not included in *Planularia*, the emendation must also be relegated to synonymy.

PLANULARIA ERIKSDALENSIS (Brotzen)
Pl. 46, figs. 5a,b

Vaginulina eriksdalensis BROTZEN, 1936, Sveriges geol. undersökning, ser. C, no. 396, p. 94, pl. 6, fig. 3.

The shape of the test of *Planularia eriksdalensis* is slender, lanceolate, greatest breadth somewhat above the middle, nearer the upper end than the initial end of the test, with dorsal edge almost entirely straight and the ventral edge slightly arcuate. The initial chamber is relatively long and narrow. The wall ornamentation is characteristic and similar on all of the specimens. On the lower part the test is covered with numerous longitudinal costae that are delicate but distinctly recognizable, extending straight or slightly veering along the chamber, with lower and upper ends pointed and lying almost parallel or at a slight angle to the dorsal edge. On the upper part are the very numerous short and fine costae, lying along the edge or near the edge of each chamber parallel to the longitudinal axis of the test, with isolated smaller costae in the area between the rows of very small costae. The dorsal and ventral edges are contained within a plain, continuous border. The hypotype measures 1.02 mm. in length, 0.32 mm. in breadth, and 0.17 mm. in thickness.

Remarks.—Only a few broken specimens were encountered, but the distinctive ornamentation leaves no doubt as to the correct placement.

Occurrence.—Studied specimens are from Member VI, Santonian. The holotype is from the Emscher-Granulatensenon (Coniacian) of Eriksdal, Schonen, Sweden.

PLANULARIA KOCHII (Roemer)
Pl. 46, figs. 6a,b

Vaginulina kochii ROEMER, 1841, Verst. norddeutsch. Kreide (1840)–1841, p. 96, pl. 15, fig. 10; CUSHMAN & ALEXANDER, 1930, Cushman Lab. Foram. Research, Contr., v. 6, no. 1, p. 1, pl. 1, figs. 1–9; TAPPAN, 1940, Jour. Paleontology, v. 14, no. 2, p. 109, pl. 17, figs. 2–4. (For complete synonymy of each of the species included in the present synonymy, see this reference and the Catalogue of Foraminifera, Spec. Pub., American Museum Nat. Hist., 1940); v. 17, no. 5, p. 500, pl. 80, figs. 17, 18; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, no. 7, p. 992, p. 969 (range chart, wherein referred to as *Vaginulina* cf. *kochii* Roemer).

Vaginulina arguta REUSS, 1860, K. Akad. Wiss. Wien., Math.-Naturw. Cl., Sitzber, v. 40, p. 202, pl. 8, fig. 4.

Vaginulina transversalis REUSS, 1860, *idem*, p. 202, pl. 8, fig. 5.

EXPLANATION OF PLATE 48

FIG. *1a–c—Gyroidina florealis* White. *1a*, umbilical view; *1b*, edge view; *1c*, spiral view; all ×62 Hypotype: UCLA no. 26654; loc. no. 50.

2a–c—Gyroidina nitida (Reuss). *2a*, umbilical view; *2b*, edge view; *2c*, spiral view; all ×53. Hypotype: UCLA no. 26655; loc. no. 56.

3a–c—Eponides bandyi Trujillo, sp. nov. *3a*, umbilical view; *3b*, edge view; *3c*, spiral view; all ×47. Holotype: UCLA no. 26656; loc. no. 47.

4a–c—Alabamina jimrothi Trujillo, sp. nov. *4a*, umbilical view; *4b*, edge view; *4c*, spiral view; all ×53. Holotype: UCLA no. 26664; loc. no. 55.

5a–c—Eponides greatvalleyensis Trujillo, sp. nov. *5a*, umbilical view; *5b*, edge view; *5c*, spiral ×50. Holotype: UCLA no. 26662; loc. no. 68.

6a–c—Eponides goudkoffi Trujillo, sp. nov. *6a*, umbilical view; *6b*, edge view; *6c*, spiral view; all ×53. Holotype: UCLA no. 26660; loc. no. 90.

7a–c—Eponides birdi Trujillo, sp. nov. *7a*, umbilical view; *7b*, edge view; *7c*, spiral view; all ×53. Holotype: UCLA no. 26658; loc. no. 58.

8a–c—Cibicides ammonoides (Reuss). *8a*, umbilical view; *8b*, edge view; *8c*, spiral view; all ×53. Hypotype: UCLA no. 26669; loc. no. 68.

9a–c—Anomalina popenoei Trujillo, sp. nov. *9a*, umbilical view; *9b*, edge view; *9c*, spiral view; all ×56. Holotype: UCLA no. 26667; loc. no. 90.

Vaginulina truncata REUSS, 1863, *idem*, v. 46, pt. 1 (1862), p. 47, pl. 3, fig. 9.
Vaginulina protosphaera REUSS, 1863, *idem*, p. 90, pl. 12, fig. 10.
Citharina kochii var. *kochii* FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ. Rept. Inv. no. 22, p. 94, pl. 1, fig. 9.

"Harp-shaped, almost as broad as long, flatly compressed, flattened dorsal edge keeled, with eight to nine low chambers, the septal walls exteriorly stand out as dark lines." The hypotype measures 1.04 mm. in length, 0.39 mm. in breadth, and 0.11 mm. in thickness.

Remarks.—The above description is a direct translation from the German text of Roemer.

The many specimens from the area of this study are extremely variable, as has been reported for the species by other authors. No two specimens are exactly alike, ranging from a subequilateral triangular shape to very elongate and narrow, and from a smooth to a lobulate ventral periphery. There seems little doubt but that these should be referred to the same species, and since *P. kochii* has priority over the other four species that fall within the range of variation, it is the name used.

The illustration of the holotype shows a raised border on the upper part of the ultimate chamber as do many of the Redding specimens, which is no doubt the beginning of an additional chamber with a strongly raised suture. The suture dividing the last two completed chambers appears to be in part raised, but the others appear to be depressed. Roemer's referral that they "stand out as dark lines" would appear to mean that they are distinct but depressed, for if the meaning of "stand out" is that they are raised, the sutures would be light colored. Cushman & Alexander (see synonymy above) give the description as follows: "Test much compressed, the sides parallel, sutures raised, wall otherwise typically smooth, periphery usually somewhat concave; aperture at the upper angle of the test, radiate."

Since the illustration shows the last suture —in the sense of the above interpretation— as definitely raised, and the species obviously so variable, the placing of specimens with entirely raised sutures in this species as has been done by previous authors is believed justifiable.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The species found in the Albian-?Cenomanian in Europe and the Gulf Coast. The holotype is from the Hilsthon (Albian) near Escherhausen, northern Germany.

PLANULARIA cf. P. SIMONDSI (Carsey)
Pl. 46, figs. 4a,b

Vaginulina simondsi CARSEY, 1926, Texas Univ. Bull., no. 2612, p. 40, pl. 2, fig. 4; MOREMAN, 1927, Jour. Paleontology, v. 1, p. 98, pl. 16, fig. 1; PLUMMER, 1931, Bureau Econ. Geol., Texas Univ. Bull., no. 3101, p. 161,162, pl. 10, figs. 13–15; CUSHMAN & TODD, 1943, Cushman Lab. Foram. Research, Contr., v. 19, p. 58, pl. 10, fig. 18; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 80, pl. 29, figs. 23–25.
Citharina simondsi FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 95, pl. 11, figs. 14,15.

The shape of the test of *Planularia simondsi* is complanate, slender, blade-like, bicarinate, dorsal edge straight, ventral edge curved, with the initial end tapered, somewhat attenuate and a suggestion of enlarging at the end which terminates with an abruptly pointed tip, and the ultimate end somewhat pointed. Chambers are indistinct. The sutures are indistinct, extending from the dorsal edge obliquely backwards. The wall is calcareous and translucent only by strong transmitted light, and ornamented by irregular longitudinal ridges or striations extending at an angle across the line of direction of the chambers, with the early ones extending across the ventral edge and the later ones not continuous from edge to edge. Aperture is at the extremity and is somewhat toothed. The hypotype measures 0.67 mm. in length, 0.28 mm. in breadth, and 0.11 mm. in thickness.

Remarks.—The widely spaced irregular costae on the specimens of this study appear typical, but as the specimens are broken and otherwise very poor, they are only tentatively placed in this species.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. Cushman (1946) gives the Gulf Coast occurrence as only in the Navarro (Maestrichtian); however, Moreman (1927, see above synonymy) figures a very typical specimen from the Eagle Ford (Turonian). The holotype is from the Navarro near

Delvalle, on Onion Creek, Travis County, Texas.

Genus KYPHOPYXA Cushman, 1929
KYPHOPYXA CHRISTNERI (Carsey)
Pl. 46, figs. 9a,b

Frondicularia christneri CARSEY, 1926, Texas Univ. Bull., no. 2612, p. 41, pl. 6, fig. 7.

Kyphopyxa christneri CUSHMAN, 1929, Cushman Lab. Foram. Research, Contr., v. 5, p. 1. pl. 1, figs. 1–7; CHURCH, 1929, Jour. Paleontology, v. 3, p. 411; CUSHMAN, 1930, Cushman Lab. Foram Research, Contr., v. 6, p. 33, pl. 4, fig. 20, ——, 1930, *idem*, p. 85, pl. 12, fig. 2; CUSHMAN & HEDBERG, 1930, *idem*, p. 65, pl. 9, fig. 5; VANDERPOOL, 1930, Jour. Paleontology, v. 4, p. 254,255 (list); CUSHMAN, 1930, Cushman Lab. Foram. Research, Spec. Pub. 2, pl. 3, fig. 2; PLUMMER, 1931, Texas Univ. Bull. 3101, p. 168, pl. 12, figs. 9–19; CUSHMAN, 1932, Jour. Paleontology, v. 6, p. 336, pl. 50, figs. 11,12; ——, 1933, Cushman Lab. Foram. Research, Spec. Pub. 5, pl. 21, figs. 1,2; LOETTERLE, 1937, Nebraska Geol. Survey, ser. 2, Bull. 12, p. 29, pl. 4, fig. 1; CUSHMAN & DEADERICK, 1942, Cushman Lab. Foram. Research, Contr., v. 18, p. 62, pl. 14, figs. 1–7; CUSHMAN, 1944, *idem*, v. 20, p. 89, pl. 13, figs. 23,24; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 92, pl. 38, figs. 12–17; ——, 1949, Maryland Dept. Geol., Mines and Water Resources, Bull. 2, p. 255, pl. 23, fig. 11; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 101, pl. 13, figs. 29–33.

The shape of the test of *Kyphopyxa christneri* is somewhat flattened, although a bit convex on either side. Initial chambers are rather irregular (usually 2–3 make the the beginning of a planispiral coil), all visible on the surface, with the later chambers diverging at their forward extremity and extending backward around the initial portion and the final few extending backward only part way. The sutures are raised, moderately thin, smooth ridges meeting in a sinuous line which extends from the initial portion almost to the aperture. The aperture is terminal. The hypotype measures 0.57 mm. in length, 0.41 mm. in breadth, and 0.14 mm. in thickness.

Remarks.—Only two complete and several broken specimens were found in the area of this study.

Occurrences.—Studied specimens are from Member VI, Santonian. Church (see above synonymy) reported the species as being very widespread but not abundant in California. The species is apparently restricted to the Americas, occurring widely in the Gulf Coast Taylor and Austin (Senonian), and the Upper Cretaceous of Maryland and Venezuela. The holotype is from the Austin Formation, Coniacian-Santonian, near Lytton Springs, Caldwell County, Texas (well core).

Genus FRONDICULARIA Defrance, 1826
FRONDICULARIA CHAPMANI Perner
Pl. 46, figs. 7a,b

Frondicularia chapmani PERNER, 1897, Ceska Akad. Cis. Frantiska Josefa, Trida 2, Nr. 4, p. 69 (Bohemian text p. 44), fig. 17; CUSHMAN, 1944, Cushman Lab. Foram. Research, Contr., v. 20, p. 111, fig. 16 (holotype redrawn).

The shape of the test of *Frondicularia chapmani* is elongate, lanceolate, the greatest breadth attained in the upper half of the length, and the edge is square. Chambers are broad. The sutures are raised above the surface, uniting in the middle and continuing to a point, with this continuation reaching almost to the lower curve of the next one (from the German resume of the Bohemian text). The hypotype measures 1.22 mm. in length, 0.32 mm in breadth, and 0.11 mm. in thickness.

Remarks.—The initial end of the holotype is missing, but in general form the specimens of this study appear indistinguishable from Cushman's re-illustration of the holotype, with the possible exception that the sutures tend to be more nearly flush. Perner's description of the sutural point extension is not borne out by the later illustration.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The holotype is from the Turonian of Lzovitz, Bohemia (Czechoslovakia).

FRONDICULARIA DURRELLI
Trujillo, sp. nov.
Pl. 46, figs. 8a,b

The shape of the test of *Frondicularia durrelli* is elongate, compressed, sides parallel, the initial end bluntly rounded with a short spine, and the apertural end acute. The periphery is smooth to slightly lobulate, while the edges are truncate, parallel, with each corner keeled. There are usually only two to six chambers following the bulbous proloculum, and these are nearly as broad as high, increasing very little in height as added, and not at all inflated. Sutures are distinct, chevron-shaped, raised, with the first few occasionally flush. The wall is calcareous, finely perforate, with each side of

the test ornamented with three to six prominent, sharp, longitudinal costae that diverge from the apex and most of which extend the entire length of the test. Aperture is terminal, strongly produced, round, radiate, but so delicate that the radial teeth are seldom preserved. The holotype measures 0.69 mm. in length, 0.25 mm. in greatest breadth, and 0.12 mm. in thickness of the adult portion.

Remarks.—The distinguishing characteristics of this species are the parallel sides, truncate edge with keeled corners, the strong, continuous costae, and the distinct limbate and raised sutures.

The species most closely resembling this is *Frondicularia elongata* White, 1928, from the Mendez Formation (Maestrichtian) of the Tampico embayment, Mexico. This Mexican species differs in having numerous strong costae that are not present on the ultimate chamber and do not cross the sutures, which are depressed.

Many of the specimens of this study were broken, and no initial portion of a microspheric form was found. The presence of the spine—and of course the large proloculum—may, therefore, not be characteristic of the microspheric generation.

The specific name is proposed in honor of Dr. Cordell Durrell, professor of geology, University of California, Los Angeles.

Additional paratypes.—UCLA no. 26632.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner sec. 35, T32N, R2W, Shasta County California. Other studied specimens are from Member IV, Coniacian, and Member VI.

Genus MARGINULINOPSIS Silvestri, 1904

MARGINULINOPSIS PRAETSCHOPPI Trujillo, sp. nov.

Pl. 46, figs. 13a,c

The shape of the test of *Marginulinopsis praetschoppi* is elongate, early portion coiled and compressed with truncate edges, the later portion uncoiled and rounded in transverse section. The chambers increase gradually in size and shape as added, with about six in the coiled portion which are compressed at first, later becoming oval and slightly inflated, and two to five in the uncoiled part, which are quite inflated, and round in transverse section of adult specimens. Sutures are initially indistinct, radial, limbate and flush, becoming more distinct, slightly curved and narrowly limbate, with the final ones distinct, depressed, nonlimbate and transverse to the axis of the test. The wall is calcareous, finely perforate, decorated with eight to sixteen sharp, mostly continuous costae that terminate near the base of the apertural neck and abruptly end or loop back on the sides of the initial portion, while several discontinuous unequal costae are developed on the truncate edge of the coiled portion between two usually distinct keels that become indistinguishable from the other costae on the adult chambers. Aperture is terminal, radiate, produced, and situated near the dorsal edge of juvenile forms, becoming central in the adult. The holotype measures 1.06 mm. in length, 0.20 mm. in thickness of coiled portion, and 0.31 mm. in diameter of the last chamber.

Remarks.—This species may be recognized by the sharp costae, the compressed early portion with truncate edges, the change in suture pattern, the produced aperture, and gradual attainment of round, inflated chambers.

The species most closely resembles *Marginulina tschoppi* Keijzer, described from the Oligomiocene Nipe Series, Oriente Province, Cuba, from which it is distinguished by the completely coiled early portion and truncate edge with two keels and intermediate unequal costae as opposed to the tricarinate Cuban species with its abruptly globose final chamber.

The truncate edge will serve to distinguish this species from the sharply keeled species *Marginulinopsis curvisepta* (Cushman) (*Marginulina curvisepta* Cushman)—often incorrectly referred to as *Marginulina jonesi* (Reuss) by the California petroleum industry—and *Marginulinopsis decurse-costata* Thalmann.

Most of the observed specimens are juvenile forms that would ordinarily be placed in the genus *Vaginulinopsis;* however, the attainment of a round transverse section in completely developed adult specimens indicates the true generic placement.

Additional paratypes.—UCLA no. 26634.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner sec, 35, T32N, R2W, Shasta County, California. Other studied specimens are from Member IV, Coniacian, and Member VI.

Genus MARGINULINA d'Orbigny, 1826

MARGINULINA LOISANA Trujillo, sp. nov.

Pl. 46, figs. 15a,b

The shape of the test of *Marginulina loisana* is elongate, large, robust, with the early part making nearly a complete coil, the later portion rectilinear, and round in transverse section. There are three to four rather indistinct chambers in the early coiled portion and about the same number in the rectilinear series, increasing rather rapidly in size and globosity as added, appressed, with the diameter about twice the height except for the last chamber which is nearly equal and more inflated. Sutures are radial and rather indistinct initially, but become distinct, depressed, and normal to the longitudinal axis in the later portion. The wall is calcareous, finely perforate, ornamented with numerous small papillae in the early portion, decreasing in number and prominence in the adult, and rarely present beyond the base of the last chamber. The aperture is terminal, very strongly produced, near the dorsal edge, and radiate, with about ten to twelve radial teeth. The holotype is 0.98 mm. in length, and 0.42 mm. in diameter of the last chamber.

Remarks.—The uniqueness of this species is attained by the robust test, small coiled portion, distinctly depressed and transverse adult sutures, strongly produced aperture, and above all—the papillose adornment of the chambers that is seldom developed beyond the base of the ultimate chamber.

Marginulina bullata Reuss is similar to this species in nearly all respects, but lacks the distinctive papillae.

The specific name is in honor of Capt. Lois E. Stephens, United States Air Force.

Additional paratypes.—UCLA no. 26636.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner sec. 35, T32N, R2W, Shasta County, California. This very striking species was encountered only in samples from the upper part of Member VI, and should make an excellent index marker.

MARGINULINA OBLIQUINODUS Bandy

Pl. 46, figs. 12a,b

Marginulina similis var. *obliquinodus* BANDY, 1951, Jour. Paleontology, v. 25, p. 498, pl. 73, fig. 2.

The shape of the test of *Marginulina obliquinodus* is elongate, tapered, nearly circular in cross section, with the early portion slightly curved with a tendency to coil and the later portion rectilinear. The chambers are closely appressed, uninflated, short in the early portion, and later lengthening rapidly. Sutures are flush, in the early part radial, those in the later portion oblique. The wall is calcareous, finely perforate, and smooth. Aperture is terminal, eccentric, located toward the outer periphery, and radiate, with about six teeth. The hypotype measures 0.63 mm. in length, and 0.21 mm. in diameter.

Occurrence.—Studied specimens were found only in Member IV, Coniacian. The holotype is from the Campanian near Carlsbad, San Diego County, California.

MARGINULINA TROEDSSONI Brotzen

Pl. 46, figs. 14a,c

Marginulina troedssoni BROTZEN, 1936, Sveriges Geol. Undersökning, Arsbok 30, Ser. C, no. 3, p. 66, pl. 4, fig. 2.

The shape of the test of *Marginulina troedssoni* is almost straight or slightly curved, *Dentalina*-like, weakly compressed, and with a small apical spine. The attitude of the first chamber indicates the placement in *Marginulina*, with those on the initial end indistinct, broader than high, then later stretched out, higher than broad, and increasing in breadth as added. Sutures are flush in the initial part and lie very obliquely while those in the upper portion are weakly depressed, wide, and slant only a little, and on the dorsal side they are highly deflected and form a series of saddles. The aperture is situated near the dorsal edge on a more or less strongly pointed, radiate cone. The

hypotype measures 0.56 mm. in length, 0.21 mm. in breadth, and 0.18 mm. in thickness.

Remarks.—In his discussion of the species Brotzen noted the differences in the two generations. Only a few of the Redding specimens are the *Dentalina*-like curved forms with apical spines. Most have a small but distinct partial coil initially and are usually somewhat compressed in a plane parallel to the axis of the coil. All have the very distinguishing dorsal suture pattern that on most specimens is even more pronounced than on the holotype.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The holotype is from the Emscher-Granulatensenon (Coniacian-Santonian) boundary of Eriksdal, Schonen, Sweden.

Genus RECTOGLANDULINA Loeblich & Tappan, 1955

RECTOGLANDULINA MUTABILIS (Reuss)

Pl. 47, figs. 2a,b

Glandulina mutabilis REUSS, 1863, K. Akad. Wiss. Wien, Math-Naturw. Cl., Sitzber. Bd. 46, Abth. 1 (1862), p. 58, pl. 5, figs. 7–11; EGGER, 1900, K. Bayer Akad. Wiss München, Math.-Physik, Cl. Abh., Bd. 21, p. 83, pl. 5, figs. 21,29; BROTZEN, 1936, Sveriges Geol. Undersökning, Ser. C, no. 396 (Arsbok 30, no. 3), p. 89, pl. 4, fig. 16.

The shape of the test of *Rectoglandulina mutabilis* is small, very variable, tending to be short or cylindrical. There are five to six chambers, with the first very bluntly rounded, and the following distinctly inflated, low, usually broader than high, the last one usually somewhat higher than broad. Sutures are transverse, depressed, except the first one which frequently is not. The aperture is terminal, radiate, on a short pointed neck. The hypotype measures 0.61 mm. in length, and 0.35 mm. in diameter.

Occurrence.—Studied specimens are from Member VI, Santonian. The type horizon or locality was not given by Reuss, but he reported the species from the Upper Hils (Aptian) and Gault (Albian) from several localities in northern Germany.

RECTOGLANDULINA PYGMAEA (Reuss)

Pl. 47, figs. 1a–1b

Glandulina pygmaea REUSS, 1851, Haidinger's Naturwiss. Abh., v. 4, pt. 1, p. 6, pl. 1, fig. 3; BROTZEN, 1936, Sveriges Geol. Undersökning, Ser. C, no. 396 (Arsbok 30, no. 3), p. 90, pl. 4, fig. 14.

The shape of the test of *Rectoglandulina pygmaea* is pointed at both ends, greatest diameter at the middle. The chambers are overlapping, with the last one making up two-thirds of the test. Sutures are indistinct, transverse. The aperture is terminal, and radiate. The hypotype measures 0.53 mm. in length, and 0.31 mm. in diameter.

Occurrence.—Studied specimens are from Member VI, Santonian. The holotype is from the Upper Cretaceous of Lemberg, Ostgalizien, Poland.

Genus DENTALINA d'Orbigny, 1839

DENTALINA ANGUSTICOSTATA Cushman

Pl. 47, figs. 9a,b

Dentalina angusticostata CUSHMAN, 1938, Cushman Lab. Foram. Research, Contr., v. 4, p. 41, pl. 6, figs. 21,22; ——, 1940, *idem*, v. 16, p. 85, pl. 14, figs. 7,8; CUSHMAN & TODD, 1943, *idem*, v. 19, p. 57, pl. 10, fig. 10; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 70, pl, 24, figs. 7,8; BANDY, 1951, Jour. Paleontology. v. 25, p. 499, pl. 73, fig. 5; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 86, pl. 9, figs. 30,31.

The shape of the test of *Dentalina angusticostata* is elongate, slender, slightly curved, and very gradually tapering. Chambers are distinct, somewhat inflated, somewhat fusiform, longer than broad, only slightly overlapping, and increasing very gradually in size as added, with the apertural chamber somewhat projecting. The sutures are distinct, depressed, and somewhat limbate. The wall is ornamented with very numerous longitudinal costae that continue across the sutures and to the apertural end. The aperture is terminal, and radiate. The hypotype measures 0.87 mm. in length, and 0.38 mm. in diameter.

Occurrence.—Studied specimens are from Member II, Middle Turonian, and Member IV, Coniacian. The original types came from the Navarro (Maestrichtian) Corsicana marl near Cooledge, Limestone County, Texas.

DENTALINA BIGHORNENSIS (Young)

Pl. 47, figs. 11a,b

Nodosaria bighornensis YOUNG, 1951, Jour. Paleontology, v. 25, p. 58, pl. 12, figs. 17,19.

The shape of the test of *Dentalina bighornensis* is straight to slightly curved, long, slender, and with an apical spine. There are

about eight chambers in the average adult specimen that are uninflated, uneven in length, inconspicuous externally, with the proloculum usually possessing a greater diameter than the next chamber, and the last chamber tapering aperturally and drawn out into a long neck. Sutures may be depressed or may be invisible. The wall is ornamented with seven to eight raised costae that do not spiral around the test, appearing first just distal to the proximal spine, dying out on the last chamber, evenly spaced, intercostal areas very wide, and consistent in size throughout their length, extending the full length of the test. The aperture is terminal, radiate. The hypotype measures 0.77 mm. in length, and 0.22 mm. in diameter.

Remarks.—The illustration of the holotype shows the test curved, as the description also states, and the aperture eccentric, and even though the sutures are not illustrated, these are criteria for placing the species in the genus *Dentalina*. The specimens of this study are also *Nodosaria*-like, but a close examination shows the sutures to be slightly oblique and generally the aperture is eccentric and test curved.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The original types are from the Turonian Frontier Formation near Rotten Grass Creek, Big Horn County, Montana.

DENTALINA CATENULA Reuss
Pl. 47, figs. 3a,b

Dentalina catenula REUSS, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl. Sitzber, Bd. 40, p. 185; CUSHMAN & CHURCH, 1929, Calif. Acad. Sci. Proc., Ser. 4, v. 18, p. 509, pl. 39, fig. 1; CUSHMAN, 1940, Cushman Lab. Foram. Research, Contr., v. 16, p. 81, pl. 13, figs. 29–34; ——, 1944, *idem*, v. 20, p. 7, pl. 1, fig. 30; ——, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 67, pl. 23, figs. 27–32; ——, 1949, Maryland Dept. Geol., Mines, and Water Res. Bull. 2, p. 251, pl. 22, fig. 11; FRIZZELL, 1954, Bureau Econ. Geol., Univ. Texas, Rept. Inv. no. 22, p. 87, pl. 9, figs. 35–37.

The shape of the test of *Dentalina catenula* is elongate, tapering, slightly curved, and initial end usually with a distinct spine. The chambers are pyriform, somewhat overlapping, of uniform shape, increasing rather uniformly in size as added, with greatest diameter below the middle and more tapering toward the apertural end. Sutures are depressed and distinct. The aperture is terminal and radiate. The hypotype measures 0.98 mm. in length, and 0.33 mm. in diameter.

Remarks.—Most of the specimens of this study are the megalospheric forms which are straighter and less tapered, but the few microspheric specimens are identical to the illustrated holotype.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species is widely reported from the Gulf Coast middle and upper Taylor beds (Campanian). The type horizon and locality was not designated, but Reuss reported the species from various localities in the Upper Gault (Albian) and Senonian of Westphalia, Germany.

DENTALINA COALVILLENSIS Peterson
Pl. 47, figs. 4a,b

Dentalina coalvillensis PETERSON, 1953, Utah Geol. Min. Survey, Bull., no. 47 (contr. Micropal., no. 1), p. 38, pl. 2, figs. 1,2; LANKFORD, 1953, *idem.*, p. 91,92, 132, pl. 16, fig. 8.

The shape of the test of *Dentalina coalvillensis* is elongate, slightly tapering, slightly curved, and the initial end usually with a distinct spine. The initial chambers are indistinct, not inflated, strongly overlapping, while the later ones are distinct, inflated, and slightly longer than broad. Sutures on the later portion are distinct, depressed, somewhat oblique. The wall is smooth. The aperture is terminal, radiate. The hypotype measures 1.18 mm. in length, and 0.13 mm. in diameter.

Remarks.—No complete specimens were found, but other than being somewhat more slender the fragments agree very well with the illustration of the holotype.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The original types were from the Upper Coloradoan or Lower Montanan (Senonian or Lower Campanian) near Coalville, Summit County, Utah.

DENTALINA cf. D. MEGALOPOLITANA Reuss
Pl. 47, figs. 5a,b

Dentalina megalopolitana REUSS, 1855, Deutsch. Geol. Ges., Zeitschr., Bd. 7, Heft. 1, p. 267, pl. 8, fig. 10.

The shape of the test of *Dentalina megalopolitana* is slightly arcuate, gently tapering in the early part, with the sides nearly

parallel in the adult. There are eight to ten chambers in the adult, and they are closely appressed. Sutures are flush, nearly transverse to the axis of the test, limbate, and straight. The wall is smooth, and finely perforate. Aperture is terminal, eccentric, and radiate. The hypotype measures 1.29 mm. in length, and 0.23 mm. in diameter.

Remarks.—A number of broken specimens have been tentatively referred to this species, although they have rather higher chambers than has the holotype.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype of the species was from the Turonian of Mecklenburg, Germany.

DENTALINA PERACUTA (Reuss)
Pl. 47, figs. 6a,b

Nodosaria (*Dentalina*) *peracuta* REUSS, 1875, Palaeontogr., Beitr. Naturg., Cassel, v. 20, pt. 2 (1872–1875), p. 86, pl. 20, fig. 21.

The shape of the test of *Dentalina peracuta* is elongate, very thin and slender, curved, and sharply tapered on the initial end. There are about nine to ten chambers, of which the first are cylindrical and indistinct, with only the last three elliptical in side view, higher than broad, and the last one tapering to a moderately long, almost central point. The sutures are distinct and transverse. The wall is smooth and vitreous looking. The hypotype measures 1.14 mm. in length, and 0.26 mm. in diameter.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype is from the Pläner (Cenomanian-Turonian) of Sachsen, Germany.

Genus NODOSARIA Lamarck, 1816

NODOSARIA ASPERA Reuss
Pl. 47, figs. 10a,b

Nodosaria (*Nodosaria*) *aspera* REUSS, Verstein, böhm. Kreideformation, pt. 1, p. 26, pl. 13, figs. 14,15.

Nodosaria aspera REUSS (*in* Geinitz), 1846, Grundriss der Verstein, p. 653, pl. 24, fig. 4; EGGER, 1900, K. Bayer Akad. Wiss., Math.-Physik. Cl., Abh., Bd. 21, Abt. 1, p. 80, pl. 8, fig. 15; FRANKE, 1928, Preuss. Geol. Landesanst., Abh., Heft 111, p. 50, pl. 4, fig. 14; CUSHMAN & JARVIS, 1932, U. S. Nat. Mus. Proc., v. 80, art. 14, p. 35, pl. 11, fig. 5; CUSHMAN, 1940, Cushman Lab. Foram. Research, Contr., v. 16, p. 88, pl. 16, fig. 2; ——, 1944, *idem*, v. 20, p. 7, pl. 1, fig. 19; CUSHMAN & DEADERICK, 1944, Jour. Paleontology, v. 18, p. 333, pl. 51, fig. 16; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 72, pl. 26, fig. 6; FRIZZELL, 1954, Bureau Econ. Geol., Univ. Texas, Rept. Inv. no. 22, p. 90, pl. 10, fig. 9.

The shape of the test of *Nodosaria aspera* is elongate, somewhat tapering, with the greatest breadth near the apertural end. The chambers are fairly distinct, subglobular, increasing rather uniformly in size as added, and somewhat overlapping. The sutures are distinct and depressed. The wall is ornamented with small, short, closely set spines that cover the entire surface. Aperture is terminal, on a slender, elongated, cylindrical neck. The hypotype measures 0.61 mm. in length, and 0.18 mm. in diameter.

Remarks.—Only a few specimens of this distinctive species were found, and apparently it is also very rare where reported by previous authors.

Occurrence.—Studied specimens are from Member IV, Coniacian. The species has been reported from the Gulf Coast Taylor (Campanian). The holotype was collected from the Plänermergel (Cenomanian-Turonian) of Luschitz, Bohemia.

NODOSARIA ORTHOPHRAGMA Egger
Pl. 47, figs. 12a,b

Nodosaria orthophragma EGGER, 1900, K. Bayer. Akad. Wiss., Math.-Physik. Cl., Abh., Bd. 21, Abt. 1, p. 62, pl. 7, fig. 8.

The shape of the test of *Nodosaria orthophragma* is elongate, completely straight, almost equally broad in the entire length, apertural end narrowing to a blunt cone, whereas the posterior end is completely rounded off. Chambers are broader than high. The sutures are limbate, not at all depressed, Aperture is a round opening at the end of the test. The hypotype measures 0.74 mm. in length, 0.28 mm. in diameter.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype is from the Senonian of Oberbayern, Germany.

NODOSARIA SPINIFERA Cushman & Campbell
Pl. 47, figs. 7a,b

Nodosaria spinifera CUSHMAN & CAMPBELL, 1935, Cushman Lab. Foram. Research, Contr., v. 11, p. 71, pl. 10, figs. 9,10.

The shape of the test of *Nodosaria spinifera* is elongate, cylindrical, and circular in

cross section. Chambers are distinct, proloculum of greater diameter than succeeding chambers which increase greatly in length as added, and in the adult are several times as long as the diameter. Sutures are indistinct and slightly depressed in the adult. The wall is thick, with numerous short, backwardly projecting spines appearing white against the darker background of the chamber wall, and in the adult but slightly projecting, appearing largely as lighter areas in the wall. The hypotype measures 0.79 mm. in length and 0.14 mm. in diameter.

Remarks.—This is the most abundant of the hyaline species in Member IV and Member VI. Cushman & Campbell (1935, p. 65) believed the fauna including this species to be correlative with the Velasco shale fauna of Mexico, now known to be Paleocene in age; however, on the basis of the species they reported, the fauna could very possibly be as old as Campanian. Inasmuch as the species is abundant in the lower Senonian of the Redding area and the Santa Ana Mountains, but absent in the Upper Campanian fauna of Bandy (1951) near Carlsbad, one may infer that the species ranges throughout all but the uppermost part of the Senonian (disregarding absence due to environmental factors). If true, the widespread and abundant distribution makes this an excellent Senonian marker.

No complete specimens were found by the authors of the species, nor have any been seen from the Redding or Santa Ana Mountains areas. It is probable that the species is not a *Nodosaria* but a *Siphonodosaria*, as the apertures of broken specimens appear to be round and not radiate. Until a complete specimen is recovered and reveals the true generic placement, however, there is little basis for transferring the species.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species is quite abundant in the Holz shale, Upper Turonian-Lower Campanian, of the Santa Ana Mountains, California. The holotype is from the Upper Cretaceous Moreno shale near Tracy, California.

NODOSARIA TENUICOSTA Reuss
Pl. 47, figs. 8a,b

Nodosaria (*Nodosaria*) *tenuicosta* REUSS, 1845, Verstein. böhm. Kreideformation, pt. 1, p. 25, pl. 13, figs. 5,6; BERTHELIN, 1880, Soc. Géol. France, Mém., ser. 3, v. 1, no. 5, p. 32, pl. 1, fig. 18; CHAPMAN, Roy. Soc. Micr., London, Jour., p. 594, pl. 9, figs. 19,20; PERNER, 1897, Ceska Akad. Cis. Frantiska Josepha, Trida 2, Nr. 4, p. 32,66, pl. 2, figs. 8,19, pl. 3, fig. 30.

The shape of the test of *Nodosaria tenuicosta* is slender, straight, rather short, upper end bluntly pointed, and apical end bearing a short spine. There are three to eight almost spherical or broadly elliptical chambers. Sutures are depressed in the adult, only slightly so or flush in the lower part. The wall is ornamented with five to seven widely spaced, very low and narrow longitudinal costae. Aperture is terminal and radiate. The hypotype measures 0.92 mm. in length, and 0.21 mm. in diameter.

Remarks.—The adult specimens with more chambers often have the last one or two chambers quite inflated, as does the holotype, but most do not and are fewer chambered.

Occurrence.—Studied specimens are from Member VI, Santonian. The holotype is from the Plänermergel (Cenomanian-Turonian) of Luschitz, Bohemia.

Family ROTALIIDAE Reuss, 1860
Genus VALVULINERIA Cushman, 1926
VALVULINERIA MARIANOSI Trujillo, sp. nov.
Pl. 47, figs. 16a–c

The shape of the test of *Valvulineria marianosi* is rotaloid, globose, sides gently convex, with two whorls visible on the spiral side, but only the final one on the umbilical side. The periphery is lobulate and edge very broadly rounded. There are usually five chambers in the ultimate whorl that are inflated, globular, and increase quite rapidly in size as added. The final chamber constitutes about one-third of the test, viewed from the umbilical side, and has a broad lip extending over the umbilical area. Sutures are deeply depressed, non-limbate, with those on the spiral side nearly radial and very slightly curved, and straight and radial on the umbilical side. Spiral suture is not at all smooth, but is formed by a series of short arcs resulting from the globular nature of the chambers. The wall is finely perforate, smooth, and usually somewhat vitreous in appearance. The aperture is interiomarginal, a rather high arch covered by the extension of the last chamber and not extending to the periphery. The holo-

type measures 0.54 mm. in length. 0.43 mm. in breadth, and 0.35 mm. in thickness.

Remarks.—This species is characterized by the overall globular test and individually, globular chambers, broadly rounded edge, deeply depressed sutures with uneven spiral suture, and low, not at all conical, spire.

Distinction from *Quadrimorphina allomorphinoides* (Reuss) is effected in part by the globosity of the test, more deeply depressed sutures and presence of several globular chambers in the initial whorl; and from *Valvulineria camerata* Brotzen and *V. camerata* Brotzen var. *umbilicata* Brotzen by several of the above points and also by the lack of a conical spire and smoothly curved spiral suture.

Optical analysis of the wall showed individual crystals to be arranged in a radial manner, and this, combined with the lack of internal partitions of the umbilical covering are criteria for not placing the species in the genus *Quadrimorphina*.

The specific name is in honor of Mr. Andrew Marianos, micropaleontologist with the Humble Oil and Refining Company, Chico, California.

Additional paratypes.—UCLA no. 26652

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner of sec. 35, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member IV, Coniacian, as well as Member VI.

Genus QUADRIMORPHINA Finlay

Quadrimorphina FINLAY, 1939, Roy. Soc. New Zealand, Trans. Proc., v. 69, pt. 3, p. 325.
Quadrimorphina TROELSEN, 1954, Dansk Geol. Foren., Meddel., v. 12, no. 4, p. 470.

The shape of the test of *Quadrimorphina* is flatly trochoid, with three to six chambers in the final whorl. The wall is of the perforate granular type and the perforations are fine. The aperture is umbilical, covered by a large rounded or triangular lip, with the umbilical lips of earlier chambers carrying low internal partitions, which run at an angle to the septal foramina, and which commonly continue on the inside of the next following umbilical lips as narrow crests.

Type species: *Quadrimorphina allomorphinoides* (Reuss) = *Valvulina allomorphinoides* Reuss, 1860 (original designation).

QUADRIMORPHINA ALLOMORPHINOIDES (Reuss)

Pl. 47, figs. 15a–c

Valvulina allomorphinoides REUSS, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber, v. 40, p. 223, pl. 11, fig. 6; EGGER, 1900, K. Bayer, Akad. Wiss., Math.-Phys. Cl., Abh., Bd. 21, Abt. 1, p. 43, pl. 2, figs. 4,5.
Discorbis allomorphinoides CUSHMAN, 1926, Amer. Assoc. Petroleum Geologists, Bull., v. 10, p. 606, pl. 20, figs. 18,19.
Allomorphina allomorphinoides WHITE, 1928, Jour. Paleontology, v. 2, p. 304, pl. 41, fig. 8.
Valvulineria allomorphinoides CUSHMAN, 1931, Cushman Lab. Foram. Research, Contr., v. 7, p. 43, pl. 6, fig. 2; BROTZEN, 1936, Sveriges Geol. Undersökning, ser. C, no. 396 (Arsbok 30, no. 3), p. 153, pl. 11, fig. 1.
(*non*) *Valvulineria allomorphinoides* CUSHMAN, 1931, Tennessee Div. Geol. Bull. 41, p. 53, pl. 9, fig. 6; CUSHMAN & JARVIS, 1932, U. S. Natl. Mus. Proc., v. 80, art. 14, p. 46, pl. 13, fig. 17; CUSHMAN & HEDBERG, 1941, Cushman Lab. Foram. Research, Contr., v. 17, p. 96, pl. 23, fig. 9; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 138, pl. 57, figs. 6,7; CUSHMAN & RENZ, 1946, Cushman Lab. Foram. Research, Spec. Pub. 18, p. 44, pl. 6, figs. 13,14; CUSHMAN, 1949, Maryland Dept. Geol., Mines and Water Res. Bull. 2, p. 263, pl. 25, fig. 12; BANDY, 1951, Jour. Paleontology, v. 25, no. 4, p. 503, pl. 74, fig. 4; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 123, pl. 18, fig. 31.

The shape of the test of *Quadrimorphina allomorphinoides* is rotaloid, with only two whorls visible on the spiral side. The inner one is very small and only a very flat button-like part shows, only occasionally is it divided by a very shallow indistinct groove, while the outer whorl increases very rapidly in breadth and forms the greatest part of the test. The chambers are rounded, only four in the last whorl, the last one very large and makes up more than half of the entire test, moderately inflated, on most specimens only the last chamber stands out. Sutures are very shallowly depressed. The aperture is rather broad, on the edge either truncate or else covered by a somewhat arched, prominent, lip-like continuation of the last chamber. The hypotype measures 0.57 mm. in length, 0.49 mm. in breadth, and 0.32 mm. in thickness.

Remarks.—This species is everywhere re-

stricted to the Senonian except in Europe where it apparently is found in the Turonian, although the writer has seen no illustrations from the Turonian—assuming the holotype is from the Senonian—and the reported occurrences may not be valid. The reported occurrences in the Maestrichtian and Paleocene of the Gulf Coast and Carribbean regions respectively are of a larger form with six to seven chambers and rounded edge. Many others with broadly rounded edges and definite spires may best be referred to *Valvulineria camerata* Brotzen, and *V. camerata* var. *umbilicata* Brotzen.

Occurrence.—Studied specimens are from Member VI, Santonian. The species is found in the Campanian near Carlsbad, California, throughout the Senonian of the Gulf Coast and Colombia, South America, and widespread in the Senonian and (?) Turonian of Europe. The type horizon and locality was not designated by Reuss, but he reported the species from the Senonian and Cuvieri-Pläner (Turonian) at various localities in Westphalia, Germany.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA FLOREALIS White
Pl. 48, figs. 1a–c

Gyroidina florealis WHITE, 1928, Jour. Paleontology, v. 2, p. 293, pl. 40, fig. 3; GALLOWAY & MORREY, 1931, Jour. Paleontology, v. 5, p. 342, pl. 38, fig. 14; GOUDKOFF, 1945, Amer. Assoc. Petroleum Geologists, Bull., v. 29, no. 7, p. 969 (chart).

(*non*) *Pulvinulinella? florealis* CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 114, pl. 59, figs. 11,12.

The shape of the test of *Gyroidina florealis* is rotaloid, planoconvex, spiral side flattened, umbilical side deeply convex, and the periphery with a rather broad, sharp keel. The sutures are limbate, curved and flush on the spiral side, and are radial and indistinct on the umbilical side. The wall is smooth on both sides. The aperture is a lunate opening at the base of the last chamber near the periphery. The hypotype measures 0.33 mm. in diameter and 0.20 mm. in thickness.

Remarks.—The fragile keel was almost always broken from the Redding specimens. Most, but not all, tend to be somewhat more truncate on the umbilical side, otherwise do not differ from the illustration of the holotype.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species ranges from the upper Papagallos beds (Upper Senonian) through the Velasco shale (Paleocene), and is also reported from the Maestrichtian of the Carribean area. The holotype is from the Velasco shale of the Tampico embayment, Mexico (well core).

GYROIDINA NITIDA (Reuss)
Pl. 48, figs. 2a–c

Rotalina nitida REUSS, 1844, Geognostiche Skizzen Böhmen, v. 2, p. 214; ——, 1845, Verstein. böhm. Kreideformation, pt. 1, p. 35, pl. 8, fig. 52; pl. 12, figs. 8,20; EGGER, 1900, K. Bayer Akad. Wiss. Math.-Phys., Cl., Abh., v. 21, p. 156, pl. 20, figs. 4–6; ——, 1908, Naturw. Ver. Passau, Heft 20, (1905–1907), p. 46, pl. 6, figs. 13–15; ——, 1910, Naturw. Ver. Regensburg, Heft 12 (1907–1909), p. 115,116, pl. 2, figs. 16–18.

Gyroidina nitida WHITE, 1928, Jour. Paleontology, v. 2, p. 296, pl. 40, fig. 6; MORROW, 1934, Jour. Paleontology, v. 8, p. 197, pl. 30, fig. 1; LOETTERLE, 1937, Nebraska Geol. Survey Bull., Ser. 2, Bull. 12, p. 42, pl. 6, fig. 8; FRIZZELL, 1943, Jour. Paleontology, v. 17, p. 351, pl. 57, fig. 6; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 140, pl. 58, fig. 5.

The shape of the test of *Gyroidina nitida* is rotaloid, nearly as high as broad, very convex, consisting of three very narrow embracing whorls, with a small umbilicus on the conical umbilical side, and the spiral side almost flat, without umbilicus, and coil scarcely projecting. The periphery is somewhat lobulate, and edge rounded. There are six high, arched chambers in each whorl, the last particularly high, or truncated. Sutures are shallowly depressed, scarcely visible in the first whorl. The wall is glossy and finely perforate. Aperture is a small slit on the inner side of the last chamber. The hypotype measures 0.38 mm. in length, 0.33 mm. in breadth, and 0.27 mm. in thickness.

Remarks.—The type description does not indicate if the sutures are limbate, but the type illustrations, although small, seemingly show this. The Redding specimens have narrowly limbate sutures that tend to be somewhat sigmoidal on the umbilical side and usually display but five chambers in the last whorl. The spiral side usually tends to be quite flat, but with some specimens, as

the illustrated hypotype, it is slightly convex.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species has been reported from the basal Niobrara (Coniacian) of Kansas, Nebraska, and South Dakota, from the Upper Cretaceous of Peru, and from the Velasco shale (Paleocene) of the Tampico embayment area of Texas. The type horizon or locality was not designated by Reuss, but he reported the species from the Plänermergel (Cenomanian-Turonian) in northwestern Bohemia.

Genus EPONIDES Denys de Montfort, 1808

EPONIDES BANDYI Trujillo, sp. nov.
Pl. 48, figs. 3a–c

The shape of the test of *Eponides bandyi* is rotaloid, usually nearly equally biconvex, robust, with about three and one-half whorls on the spiral side, and only the final one visible on the umbilical side. The periphery is slightly lobulate and the edge rather sharply rounded. There are usually six chambers visible on the umbilical side, increasing slowly and regularly in size as added. The final septal face is sigmoidal, with the backwardly projecting arc near the periphery, and the inner end of the final chamber usually covering the point of intersection of the sutures on the umbilical side as the result of the tendency for the complete chamber to shift in that direction. Sutures are limbate and distinct, on the spiral side flush, only slightly curved, tending to be somewhat tangential, with the last suture and final portion of the spiral suture depressed and non-limbate occasionally if the ultimate chamber is shifted toward the umbilical side, while on the umbilical side they are sigmoidal and very slightly if at all depressed. The wall is calcareous, finely perforate, and smooth except for the occasional gerontic tendency of the last chamber to be slightly roughened on the umbilical side. The aperture is interiomarginal, a long low slit extending about one-half to two-thirds the length of the chamber from its inner end, and occasionally with a slight lip. The holotype measures 0.53 mm. in diameter and 0.38 mm. in thickness.

Remarks.—The species is unique in possessing nearly equal biconvexity, sigmoidal sutures on the umbilical side, and an elongate, slit-like aperture.

This large, rather distinctive species was found in sufficient abundance to serve as an excellent index fossil, although the youngest age of the sediments yielding it was not determined in this study.

While a close relationship to the three other new species of *Eponides*—*E. birdi*, *E. goudkoffi*, and *E. greatvalleyensis*—described in this paper is apparent, there were found only a few specimens that appeared gradational with *E. goudkoffi*.

The specific name is in honor of Dr. Orville L. Bandy, professor of geology, University of Southern California, Los Angeles.

Additional paratypes.—UCLA no. 26657.

Occurrence.—The holotype is from Member IV, Coniacian, locality 47, on Clover Creek, about 1900 feet east and 900 feet north of the SW corner of sec. 32, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member VI, Santonian as well as Member IV.

EPONIDES BIRDI Trujillo, sp. nov.
Pl. 48, figs. 7a–c

The shape of the test of *Eponides birdi* is rotaloid, lenticular, nearly equally biconvex, with usually about three whorls on the spiral side, and only the final one visible on the umbilical side. The periphery is smooth and the edge sharply rounded. There are about ten chambers in the ultimate whorl, increasing very slowly and regularly in size as added, with the last septal face retaining nearly the same height along its entire length and sharply depressed near the periphery. On the spiral side the sutures are rather widely limbate, flush, somewhat tangential, and gently curved, while on the umbilical side they are curved to slightly sigmoidal, flush or tending to be raised, narrowly limbate toward the periphery, thence widening and fusing into a distinct central umbo. The wall is calcareous, finely perforate, smooth except for the central umbo which is only slightly raised, and an occasional specimen displays a gerontic tendency for the final chamber to be a trifle depressed on the umbilical side. The aperture

is interiomarginal, an elongate slit extending from the inner end about two-thirds the length of the chamber, usually with an incipiently developed lip. The holotype measures 0.47 mm. in diameter, and 0.28 mm. in thickness.

Remarks.—The distinguishing characteristics of this species are the smooth periphery, large number of chambers, incipient apertural lip, and paramountly, the distinct sutures that fuse into a central umbo on the umbilical side.

The first few sutures on the umbilical side usually appear only simply curved and not sigmoidally so, probably because they are fused along more of their length than are the later ones.

This species is found in the Coniacian frequently enough to be of stratigraphic value, but this is not so in the Santonian sediments.

The specific name is in honor of C. Vaughn Bird, geologist, with the Humble Oil and Refining Company, Los Angeles, California.

Additional paratypes.—UCLA no. 26659.

Occurrence.—The holotype is from Member IV, Coniacian, locality 58, on Clover Creek, about 1800 feet west and 2000 feet south of the NE corner of sec. 32, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member VI, Santonian, as well as. Member IV.

EPONIDES GOUDKOFFI Trujillo, sp. nov.
Pl. 48, figs. 6a–c

The shape of the test of *Eponides goudkoffi* is rotaloid, subconical, about three and one-half whorls visible on the spiral side, the ultimate one only on the umbilical side, with the umbilical side strongly convex and the spiral side only gently so and usually concave just within the periphery. The periphery is lobulate and edge acute but not keeled. There are normally six chambers visible in the final whorl, increasing rather slowly and regularly in size as added, with the peripheral margin of each often extending beyond the immediately adjacent area of the spiral side, and the final one with a prominent inner end and septal face somewhat club-shaped in profile, with the narrow end at the periphery and backwardly depressed about midway. Sutures are distinct, limbate, on the spiral side gently curved, subtangential and flush, while on the umbilical side they are sigmoidal and slightly depressed. The wall is calcareous, finely perforate, and smooth. The aperture is interiomarginal, a long low arch situated medially or toward the inner end, and extending about one-third the length of the chamber. The holotype measures 0.48 mm. in diameter, and 0.38 mm. in thickness.

Remarks.—The lobulate periphery, acute edge, sigmoidal sutures on the umbilical side, which is strongly convex, and gently convex spiral side with the subperipheral area usually concave will serve to distinguish this species from all others.

A few specimens seem to be gradational with *E. bandyi*—a new species also described in the present paper—but the greater number are easily distinguished by the acute edge, different convexity, and the character of the last chamber.

The specific name is in honor of the late Mr. Paul P. Goudkoff, in recognition of his outstanding work in stratigraphic micropaleontology in the Upper Cretaceous of California.

Additional paratypes.—UCLA no. 26661.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of a gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner of sec. 35, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member IV, Coniacian, as well as Member VI.

EPONIDES GREATVALLEYENSIS Trujillo, sp. nov.
Pl. 48, figs. 5a–c

The shape of the test of *Eponides greatvalleyensis* is rotaloid, spiral side convex, and umbilical side nearly flat, only gently convex, with about three and one-half whorls in the spire, only the last visible on the umbilical side. The periphery is slightly lobulate, and edge is rather acute. There are about six chambers in the ultimate whorl, increasing rather slowly in size as added, with the final septal face very narrow. Sutures on the spiral side are flush, limbate, gently curved and subtangential, while on the umbilical side they are sigmoidal, flush or slightly raised, becoming wider and dis-

tinctively limbate at the inner ends where they fuse. The wall is calcareous, finely perforate, and smooth except for the umbilical side of the final chamber which in most specimens becomes quite granular and occasionally extends peripherally, or a portion is somewhat elevated or depressed, probably a gerontic feature that is lacking in juvenile specimens. Aperture is interiomarginal, a rather highly arched slit extending from near the inner end about one-half the length of the chamber, and with a distinct narrow lip on well preserved specimens. The holotype measures 0.46 mm. in diameter, and 0.26 mm. in thickness.

Remarks.—This species may be recognized by the strongly convex spiral side, nearly flat umbilical side with sigmoidal sutures, usually deformed final chamber, and the distinct apertural lip.

Rotalina badensis Czjzek, 1948 (*non Rotalina badensis* Kübler & Zwingli, 1870) from the Austrain Miocene, apparently differs only in the lack of sigmoidal sutures on the umbilical side, and perhaps in the character of the final chamber.

So few specimens of this distinctive species were found as to be of little value stratigraphically, even though found only in the Coniacian.

Additional paratypes.—UCLA no. 26663.

Occurrence.—The holotype is from Member IV, Coniacian, locality 68, on Clover Creek, about 300 feet northwest of the SE corner sec. 29, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from other localities in Member IV.

Genus ALABAMINA Toumin, 1941
ALABAMINA JIMROTHI Trujillo, sp. nov.
Pl. 48, figs. 4a–c

The shape of the test of *Alabamina jimrothi* is rotaloid, small, subglobular, planoconvex, about three rather strongly embracing whorls visible on the flat spiral side, but only the ultimate whorl visible on the umbilical side, which is quite convex and hemispherical. The periphery is slightly lobulate, and the edge is sharply rounded. There are usually five or six chambers in the final whorl, increasing quite rapidly in thickness, with the axis of coiling for the last few chambers moving such that only the inner ends of the last two or three meet at a common point. The last septal face is high, subcrescentic in profile, with a deep, sharply angular indentation that is characteristic of the genus, and the resultant peripheral end forming a finger-like projection extending a short distance in the plane of coiling. Sutures are distinct, very narrowly limbate and tending to be non-limbate, on the spiral side slightly curved, subtangential, flush or with the last one or two and latter part of the spiral suture shallowly depressed, with the spiral suture of the final whorl forming a somewhat polygonal figure, while on the umbilical side they are nearly radial, gently curved, usually indistinctly limbate, and flush or very slightly depressed. The wall is calcareous, finely perforate, and smooth. Aperture is interiomarginal, an elongate arch extending from near the inner end of the chamber to the angular indentation. The holotype measures 0.44 mm. in diameter, and 0.35 mm. in thickness.

Remarks.—The uniqueness of this new species—other than generic characteristics—is exemplified by the planoconvex, subglobular, hemispherical test, shifting of the axis of coiling, narrowly limbate sutures, and very elongate aperture.

Of the relatively few species thus far included in the genus, none is markedly similar and the above diagnostic features will easily distinguish this new species.

Apparently, this is the first reported occurrence of the genus in rocks as old as Coniacian in age, for the acme of the lineage seems to have been reached during Paleocene-Eocene time, and only a few species are present in the Late Cretaceous.

The specific name is in honor of Mr. Jim C. Roth, geologist, University of California, Los Angeles.

Additional paratypes.—UCLA no. 26665.

Occurrence.—The holotype is from Member IV, Coniacian, locality 55, on Clover Creek, in the approximate center of sec. 32, T32N, R2W, east of Redding, Shasta County, California. The species occurs rather abundantly in the Coniacian, but in lesser numbers in Member VI, Santonian.

Genus ANOMALINA d'Orbigny, 1826
ANOMALINA COMPLANATA Reuss
Pl. 49, figs. 1a–c

Anomalina complanata REUSS, 1851, Naturw. Abh., Vienna, Bd. 4, Abth. 1, p. 36, pl. 4, fig. 36. (For complete synonymy of European

Publications to 1940, see the Catalogue of Foraminifera, Spec. Pub., Amer. Mus. Natl. Hist., 1940.)

The shape of the test of *Anomalina complanata* is rotaloid, rather circular, very compressed, umbilical side slightly convex, spiral side almost flat, both sides very shallowly umbilicate, with the inner whorl on the spiral side more extensive than on the umbilical side, and the edge very acute. There are twelve narrow, curved, smooth chambers in the last whorl. Sutures are narrow, very shallowly depressed, and only those between the last chambers are somewhat distinct. The wall is punctate. (Aperture is interiomarginal, extending a short distance along the spiral suture of the umbilical side and onto the periphery, occasionally with a narrow lip.) The hypotype measures 0.45 mm. in length, 0.38 mm. in breadth, and 0.15 mm. in thickness.

Remarks.—The specimens of this study agree very well with the holotype illustration, seemingly differing only in usually but not always having two or three less chambers and the later portion of the periphery slightly lobulate. Reuss did not give an apertural description, but the illustration indicates the aperture to be as given above, as are the present specimens, which, in addition, occasionally display a narrow lip.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The few previously reported American occurrences have subsequently been or should be relegated to other species. The species occurs rather extensively in the European Upper Cretretaceous, and the holotype is from Lemburg, Poland.

ANOMALINA POPENOEI Trujillo, sp. nov.
Pl. 48, figs. 9a–c

The shape of the test of *Anomalina popenoei* is rotaloid, compressed, spiral side rather flattened or slightly convex, umbilical side gently convex, with usually one and one-half to two whorls visible on the spiral side, and only one on the umbilical side which tends to be slightly evolute. The periphery is lobulate and the edge acute and keeled. There are usually ten chambers in the ultimate whorl, increasing gradually and regularly in size as added, and are uninflated and crescentiform in shape. Sutures on both sides are widely limbate, raised, sweeping strongly back and tangential at the periphery to form the acutely keeled edge, on the spiral side the spiral suture may be depressed or slightly raised, while on the umbilical side it is only incipiently developed and depressed. The wall is calcareous, mediumly punctate, smooth or occasionally very finely granular in appearance, except for the raised sutures and a secondary thickening of shell material on both sides forming central umbos that are quite variable in size and often barely discernible. Aperture is interiomarginal, a low arched opening on the umbilical side, extending along the entire base of the final chamber, but not crossing the periphery, and occasionally adorned with an indistinct lip. The holotype measures 0.46 mm. in length, 0.37 mm. in breadth, and 0.16 mm. in thickness.

Remarks.—The distinguishing characteristics of this new species are the compressed test with keeled edge, the limbate, raised, strongly curved sutures, nearly involute umbilical side, and variable umbos.

There is a superficial resemblance to *Planulina spissocostata* Cushman, 1938, but it differs in the nearly involute umbilical side, the position of the aperture, more strongly raised sutures, and about one-third fewer chambers.

This is one of the most distinctive species of benthonic rotaloid foraminifers found in the Redding area, and should make an excellent marker.

The specific name is in honor of Dr. Willis P. Popenoe, professor of geology, University of California, Los Angeles, in recognition of his years of outstanding work with the paleontology and stratigraphy of the California Upper Cretaceous.

Additional paratypes.—UCLA no. 26668.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner of sec. 35, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member IV, Coniacian, as well as other localities in Member VI.

Genus CIBICIDES Denys de Montfort, 1808

CIBICIDES AMMONOIDES (Reuss)
Pl. 48, figs. 8a–c

Rosalina ammonoides REUSS, 1844, Geog. Skiz-

zen Böhm., v. 2, p. 214; ——, 1845 Verstein. böhm. Kreideformation, Abt. 1, p. 36, pl. 8, fig. 53; pl. 13, fig. 66; ——, 1851, Naturw. Abh., v. 4, p. 36, pl. 4, fig. 2; BEISSEL, 1891, K. Preuss. Geol. Landesanst., Abh., Heft 3, p. 74, pl. 16, figs. 1–5; pl. 1, fig. 9.

The shape of the test of *Cibicides ammonoides* is rotaloid, circular, compressed, spiral side composed of three distinct whorls, slightly concave in the middle, outer whorl convex, and the umbilical side strongly umbilicate. There are about seven chambers in each whorl, with the last ones strongly arched and the remaining few very small, somewhat oblique and curved. The sutures on the spiral side are shallow, curved, straightening toward the outer edge, and less curved on the umbilical side. (Aperture interiomarginal, a low slit extending a short distance along the spiral suture and onto the periphery.) The hypotype is 0.39 mm. in diameter and 0.18 mm. in thickness.

Remarks.—Reuss described the species in 1844, but not until 1845 did he illustrate any specimens from Bohemia. Both illustrations show eight chambers in the final whorl, and although rather indistinct, figure 66 indicates a typical *Cibicides* aperture, as has been described above, since the original description mentioned no apertural characteristics.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype is from the Plänermergel (Cenomanian-Turonian) of Luschitz, Bohemia.

Family CERATOBULIMINIDAE Glaessner, 1945

Genus LAMARCKINA Berthelin, 1881

LAMARCKINA REEDANA Trujillo, sp. nov.

Pl. 47, fig. 13a–c

The shape of the test of *Lamarckina reedana* is rotaloid, compressed, gently biconvex, both sides revealing but the ultimate whorl, although the spiral side tends to be somewhat evolute, and the umbilical side displays a deep and wide umbilicus. The periphery is smooth in the initial portion, later becoming lobulate, and with a rounded or subacute edge adorned with a pseudokeel. There are usually eight chambers visible on both sides, with those of the umbilical side almost indiscernible, while on the spiral side the first three to five are flattened and indistinct, the last three to five distinct, quite inflated, and the ultimate chamber often abruptly longer than the penultimate one. Sutures are nonlimbate, on the umbilical side they are flush or slightly depressed in later portion, very indistinct, nearly radial, very slightly curved, while on the spiral side they are gently curved, with the first three to five rather indistinct, flush or slightly depressed, and the remainder distinct, very depressed. The wall is calcareous, smooth, finely perforate on the spiral side, the umbilical side with a polished secondary thickening, with a distinct pseudo-keel formed along the edge where the secondary thickening terminates. Aperture is interiomarginal,

EXPLANATION OF PLATE 49

FIG. *1a–c—Anomalina complanata* Reuss. *1a*, umbilical view; *1b*, edge view; *1c*, spiral view; all ×58. Hypotype: UCLA no. 26666; loc. no. 16.

2a–c—Ceratobulimina cretacea Cushman & Harris. *2a*, umbilical view; *2b*, edge view; *2c*, spiral view; all ×62. Hypotype: UCLA no. 26673; loc. no. 61.

3a–c—Höglundina supracretacea (tenDam). *3a*, umbilical view; *3b*, edge view; *3c*, spiral view; all ×58. Hypotype: UCLA 26675; loc. no. 58.

4a–c—Höglundina lacunosa (Loeblich & Tappan). *4a*, umbilical view; *4b*, edge view; *4c*, spiral view; all ×58. Hypotype: UCLA no. 26674; loc. no. 20.

5a–c—Rugoglobigerina kingi Trujillo, sp. nov. *5a*, umbilical view; *5b*, edge view; *5c*, spiral view; all ×58. Holotype: UCLA no. 26678; loc. no. 63.

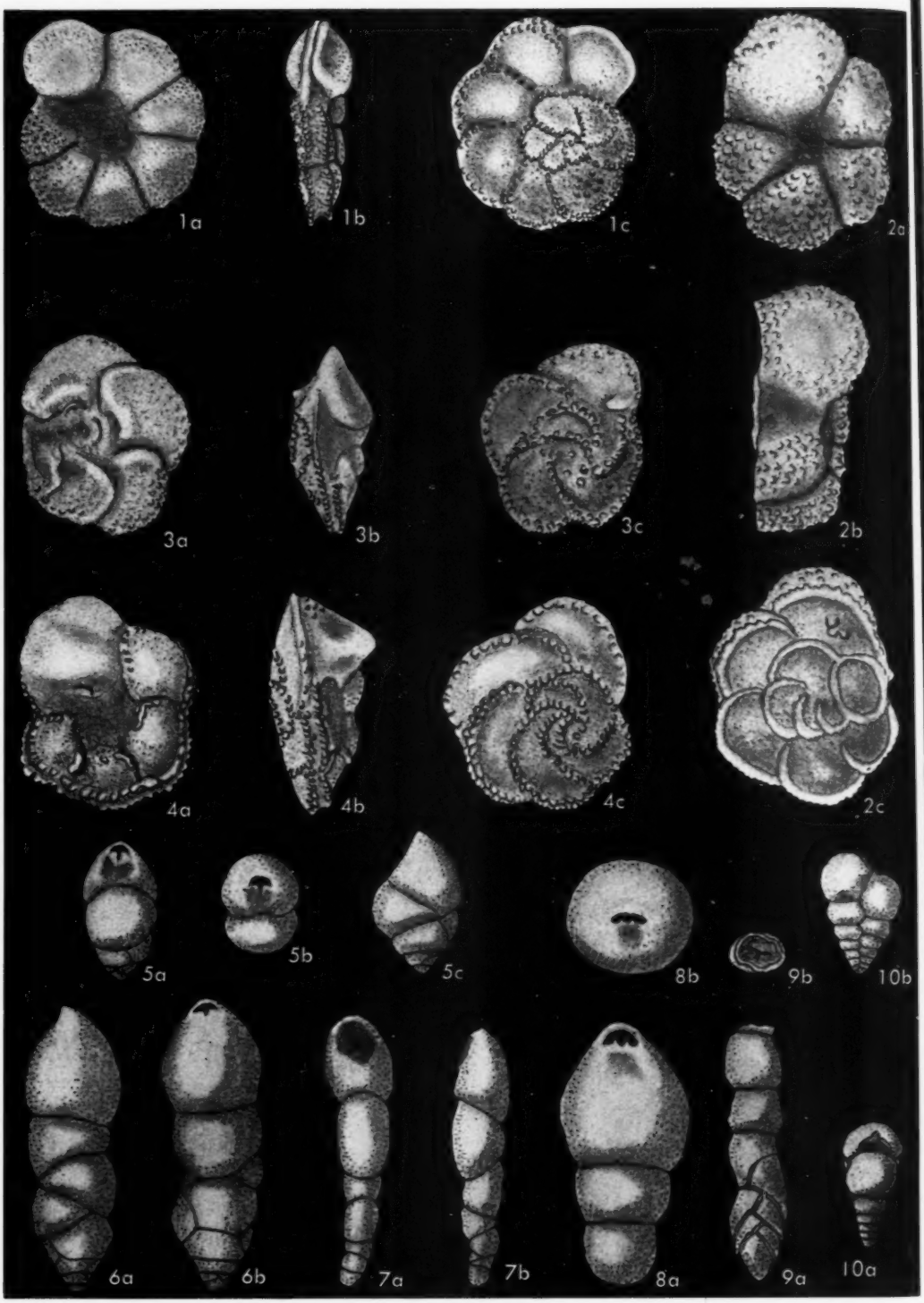
6a–c—Rugoglobigerina praehelvetica Trujillo, sp. nov. *6a*, umbilical view; *6b*, edge view; *6c*, spiral view; all ×58. Holotype: UCLA no. 26680; loc. no. 20.

7a–c—Praeglobotruncana hantsbollii Trujillo, sp. nov. *7a*, umbilical view; *7b*, edge view; *7a*, spiral view; all ×62. Holotype: UCLA no. 26676; loc. no. 44.

8a–c—Globotruncana linneiana (d'Orbigny). *8a*, umbilical view; *8b*, edge view; *8c*, spiral view; all ×62. Hypotype: UCLA no. 26684; loc. no. 52.

9a–c—Globotruncana schneegansi Sigal. *9a*, umbilical view; *9b*, edge view; *9c*, spiral view; all ×62. Hypotype: UCLA no. 26687; loc. no. 20.

1a
1b
1c
2a
2b
2c
3a
3b
3c
4a
4b
4c
5a
6a
7a
8a
9a
5b
6b
7b
8b
9b
5c
6c
7c
8c
9c


1a
1b
1c
2a
3a
3b
3c
2b
4a
4b
4c
2c
5a
5b
5c
8b
9b
10b
6a
6b
7a
7b
8a
9a
10a

indistinct, opening into the umbilicus beneath a slight fold. The holotype measures 0.39 mm. in length, 0.33 mm. in breadth, and 0.20 mm. in thickness.

Remarks.—The unique characteristics of this species are the rounded to subacute edge, the chambers on the spiral side which are flattened initially and later quite inflated, and the nonlimbate sutures that are deeply depressed only in the final portion of the spiral side.

There is not a great difference between any of the species of *Lamarckina*, most of which occur in the Eocene; however, the above characteristics, and especially the suture pattern, will serve to distinguish this species from the most similar ones.

This is one of the most distinctive and numerous of the benthonic species found in Member II, and should make an excellent Turonian marker.

The specific name is in honor of Mr. and Mrs. Frank. C. Reed of Canoga Park, California.

Additional paratypes.—UCLA no. 26671.

Occurrence.—The holotype is from Member II, Middle Turonian, locality 20, on the west bank of Salt Creek just south of U. S. Route 299, about 1600 feet east and 2300 feet south of the NW corner of sec. 35, T32N, R3W, east of Redding, Shasta County, California.

LAMARCKINA STORMI Brotzen
Pl. 47, figs. 14a–c

Lamarckina stormi BROTZEN, 1936, Sver. Geol. Unders. Abh., Ser. C, no. 396 (Arsbok 30, no. 3), p. 150, pl. 10, fig. 7.

The shape of the test of *Lamarckina stormi* is rotaloid, small, cap-shaped, umbilical side flattened, weakly depressed, and the spiral side conical, with two to three whorls that increase rapidly in width. A large, wide umbilicus is on the umbilical side, and the edge of the test is rounded. In the final whorl, there are five to six long, crescentically curved chambers. The sutures on the spiral side are wide, slightly elevated, while on the umbilical side they appear indistinct and very weakly depressed. The aperture is interiomarginal, on the umbilical side, and with a small lip. The hypotype measures 0.51 mm. in length, 0.44 mm. in breadth, and 0.22 mm. in thickness.

Remarks.—Only a few, but very typical, specimens of this species were found, occurring here in rocks somewhat older than in Sweden.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The holotype

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EXPLANATION OF PLATE 50

FIG. *1a–c—Globotruncana canaliculata* (Reuss), *sensu stricto*. *1a*, umbilical view; *1b*, edge view; *1c*, spiral view; all ×58. Hypotype: UCLA no. 26682; loc. no. 57.

2a–c—Globotruncana helvetica Bolli. *2a*, umbilical view; *2b*, edge view; *2c*, spiral view; all ×58. Hypotype: UCLA no. 26683; loc. no. 20.

3a–c,4a–c—Globotruncana renzi Gandolfi. *3a,4a*, umbilical view; *3b,4b*, edge view; *3c,4c*, spiral view; all ×58. Hypotypes: fig. *3*—UCLA no. 26685; fig. *4*—UCLA no. 26886; both loc. no. 20.

5a–c,6a–c—Pleurostomella greatvalleyensis Trujillo, sp. nov. *5a*, front view; *5b*, terminal view; *5c*, side view. *6a*, side view; *6b*, front view; all ×67. Paratype—fig. *5*—UCLA no. 26691; Holotype—fig. *6*—UCLA 26690; both loc. no. 90.

7a,b—Pleurostomella subnodosa Reuss. *7a*, front view; *7b*, side view; both ×58. Hypotype: UCLA no. 26693; loc. no. 48.

8a,b—Nodosarella wintereri Trujillo, sp. nov. *8a*, front view; *8b*, terminal view; both ×59. Holotype: UCLA no. 26694; loc. no. 90.

9a,b—Tubitextularia cf. *T. cretacea* (Cushman). *9a*, side view; *9b*, terminal view; both ×105. Hypotype: UCLA no. 26689; loc. no. 42.

10a,b—Heterohelix globulosa (Ehrenberg). *10a*, edge view; *10b*, side view; both ×72. Hypotype: UCLA no. 26688; loc. no. 64.

is from the Emscher-Granulatensenon (Coniacian-Santonian) boundary of Eriksdal, Schonen, Sweden.

Genus CERATOBULIMINA Toula, 1915
CERATOBULIMINA CRETACEA Cushman & Harris
Pl. 49, figs. 2a–c

Ceratobulimina cretacea CUSHMAN & HARRIS, 1927, Cushman Lab. Foram. Research, Contr., v. 3, no. 51, p. 173, pl. 29, fig. 1; pl. 30, fig. 11; CUSHMAN, 1931, Tennessee Div. Geol. Bull. 41, p. 56, pl. 10, fig. 2; PLUMMER, 1936, Am. Midland Naturalist, v. 17, p. 460, text fig. 5; CUSHMAN & TODD, 1943, Cushman Lab. Foram. Research, Contr., v. 19, p. 70, pl. 12, fig. 7; BANDY, 1951, Jour. Paleontology, v. 25, p. 507, pl. 73, fig. 20; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rept. Inv. no. 22, p. 125, pl. 19, fig. 13.

The shape of the test of *Ceratobulimina cretacea* is rotaloid, small, slightly longer than broad. There are usually seven chambers in the final whorl. Sutures are distinct, limbate, but not raised. The wall is smooth and polished. Aperture is interiomarginal, extending slightly into the final chamber in a rounded triangular opening, and covered in well preserved specimens with a slightly developed thin plate that is attached above the inner end of the aperture. The hypotype measures 0.34 mm. in length, 0.26 mm. in breadth, and 0.21 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian. The species is found in the Campanian near Carlsbad, California, and is rather widespread in the Maestrichtian of the Gulf Coastal region. The holotype is from the Maestrichtian Navarro Formation, Mexia Oil Field, Mexia, Texas.

Genus HÖGLUNDINA Brotzen, 1948
HÖGLUNDINA LACUNOSA (Loeblich & Tappan)
Pl. 49, figs. 4a–c

Epistomina lacunosa LOEBLICH & TAPPAN, 1946, Jour. Paleontology, v. 20, p. 256, pl. 37, figs. 16,17.

The shape of the test of *Höglundina lacunosa* is rotaloid, biconvex, with the umbilical area filled and periphery keeled. Chambers are numerous, six to seven in the last whorl, and increasing in size as added. Sutures are raised and limbate, particularly on the umbilical side, occasionally somewhat nodose in appearance, curved backward on the spiral side, and straight on the umbilical side. The wall is calcareous, very coarsely perforate, with the surface ornamented by the limbate, occasionally nodose raised sutures, and large pitlike perforations. The primary aperture is oval in outline, in the central part of the apertural face near the peripheral keel on the umbilical side. The supplementary apertural slits are at the peripheral margin of the umbilical side, distinct, and are usually filled with clear shell material. The hypotype measures 0.40 mm. in diameter, and 0.25 mm. in thickness.

Remarks.—The tests of the Redding specimens are all filled and the character of the aperture is not clear on any specimen, but appears to be the same as given in the type description.

Occurrence.—Studied specimens are from Member II, Middle Turonian, where the species occurs in appreciable numbers. The holotype is from the Albian, Washita Group, Denton Formation, Gainesville, Cooke County, Texas.

HÖGLUNDINA SUPRACRETACEA (ten Dam)
Pl. 49, figs. 3a–c

Epistomina supracretacea TEN DAM, 1948, Inst. Fran. Petrole, Rev., v. 3, no. 6, p. 163, pl. 1, fig. 3 (reproduced from Cushman, 1946, pl. 59, fig. 2).

Höglundina supracretacea BANDY, 1951, Jour. Paleontology, v. 25, p. 507, pl. 74, fig. 3 (see this reference for synonymy to 1951).

The shape of the test of *Höglundina supracretacea* is rotaloid, circular, biconvex, spire regular, composed of two and one-half to three whorls, umbilical side sometimes more convex than the spiral side, with edge acute and lightly keeled. There are six to eight chambers in the last whorl, triangular shaped on the umbilical side, a little wider than high, increasing very gradually in size. Sutures are strongly limbate, flush with the test or slightly raised; on the spiral side they are tangential, while on the umbilical side they are straight, radial or lightly tangential, fusing into a small, central umbo. The wall is smooth. Aperture is interiomarginal, elongate, and near the periphery on the umbilical side, with acces-

sory apertures parallel to and near the periphery on the umbilical side.

Remarks.—The size of the umbilical umbo is rather variable in the Redding specimens, and there is often secondary thickening on the central area of the spiral side. Those specimens found in Member II tend to have a very small umbo and a larger test than those in Members II and VI.

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The species has been reported from the Campanian of the Carlsbad, California area, from the Campanian and Maestrichtian of the Gulf Coastal region, and the Upper Cretaceous of Europe. The figure ten Dam reproduced (no holotype was designated) is of a specimen from the Taylor (Campanian) near Adamsville, McNairy County, Tennessee.

Family ORBULINIDAE Schultze, 1854
Genus PRAEGLOBOTRUNCANA
Bermudez, 1952
PRAEGLOBOTRUNCANA HANSBOLLII
Trujillo, sp. nov.
Pl. 49, figs. 7a–c

The shape of the test of *Praeglobotruncana hansbollii* is rotaloid, small, compressed, sides nearly parallel, usually with about two and one-half whorls visible in the flattened spire, and only the last whorl visible on the umbilical side. The periphery is lobulate, and edge evenly rounded. There are usually six chambers in the ultimate whorl, which increase very gradually and regularly in size as added, except the penultimate and ultimate ones which tend to be more inflated. Sutures are distinct, quite depressed, straight and radial on both sides. The wall is calcareous, with medium sized perforations, and slightly hispid. The umbilicus is shallow, relatively wide, with an incipient cover plate occasionally observable. Aperture is interiomarginal, a low arched slit extending from the umbilical side onto the peripheral margin, and with a slight, usually indistinct lip. About 65 percent of the observed specimens coil dextrally. The holotype measures 0.24 mm. in length, 0.20 mm. in breadth, and 0.08 mm. in thickness.

Remarks.—This new species is unique in having both sides flat, little increase in size of chambers, a very shallow umbilicus, the aperture extending from the umbilical side onto the peripheral margin, and the wall slightly hispid.

The species most closely resembling this new species is *P. planispira* (Tappan) =*Globigerina planispira* Tappan, 1940, the type description and illustration of which are in error in portraying the wall as smooth—it is hispid, according to Miss Ruth Todd of the U. S. National Museum (personal communication). She advised the writer that the figure of the hypotype from the Albian of England (U. S. Natl. Mus. Bull. 215, 1957, pl. 9, fig. 3) is quite typical of the several types from Texas in the Museum collections.

Several specimens of the new species were sent to Miss Todd for comparison with the types of *P. planispira*, and she answered " . . . I believe that yours are not the same. They are considerably flatter and do not have such a depressed umbilical area as does *planispira*." In addition to this, it appears that the aperture of *P. planispira* does not extend as a low slit onto the peripheral margin as with the new species.

The specific name is in honor of Dr. Hans Bolli, micropaleontologist, in recognition of his fine contributions to the science of micropaleontology.

Additional paratypes—UCLA no. 26677.

Occurrence.—The holotype is from Member IV, Coniacian, locality 44, on Clover Creek, about 500 feet north and 1200 feet east of the SW corner of sec. 32, T32N, R2W, east of Redding, Shasta County, California. Many of the Coniacian sample localities yielded this distinctive species in sufficient numbers to make it a valuable index fossil with an apparently short range, at least in the area of this study.

Genus RUGOGLOBIGERINA Bronniman, 1952
RUGOGLOBIGERINA KINGI
Trujillo, sp. nov.
Pl. 49, figs. 5a–c

The shape of the test of *Rugoglobigerina kingi* is rotaloid, compressed, spiral side gently convex, umbilical side flattened,

with about three whorls visible in the spire and only the last one visible on the umbilical side. The periphery is lobulate and edge is rounded. There are six to eight inflated chambers in the ultimate whorl that increase regularly in size as added. Sutures are distinct, depressed, straight and radial on both sides. The wall is calcareous, perforate, rugose, but rather variable in the amount of rugosity, with the ultimate chamber often smooth or nearly so. The umbilicus is quite deep and relatively large. Aperture is interiomarginal, opening into the umbilicus, forming a rather high arch with an indistinct lip. Coiling of observed specimens is random, both sinistral and dextral, in about equal numbers. The holotype measures 0.37 mm. in diameter and 0.21 mm. in thickness.

Remarks.—Characteristic features of this new species are the convex spiral side, flattened and deeply umbilicate umbilical side, number of chambers, final chamber tending to be smooth, and the high arched aperture.

This species differs from *R. praehelvetica* (a new species also described in the present paper) primarily in having an evenly convex spiral side and less rapidly expanding chambers.

The specific name is in honor of Dr. Philip B. King, geologist, the United States Geological Survey, in recognition of his outstanding contributions to the field of geology.

Additional paratypes—UCLA no. 26679.

Occurrence.—The holotype is from Member IV, Coniacian, locality 63, on Clover Creek, about 1200 feet west and 800 feet south of the NE corner of sec. 32, T32N, R2W, east of Redding, Shasta County, California. A sufficient number of specimens was found in most of the Member IV localities, indicating this planktonic species may prove to be an important Coniacian marker.

Rugoglobigerina praehelvetica Trujillo, sp. nov.

Pl. 49, figs. 6a–c

The shape of the test of *Rugoglobigerina praehelvetica* is rotaloid, spiral side flattened, about two and one-half whorls constituting the spire, in transverse section the individual whorls are rounded on the spiral side and in some specimens the latter part of the ultimate whorl becomes somewhat angular, with the inner whorls occasionally raised to a common level above the outer whorls. The periphery is lobulate, and the edge is very broadly rounded. There are usually five or six chambers in the ultimate whorl that are quite inflated and increase rather rapidly in size as added. Sutures are distinct, depressed, straight and radial on both sides. The wall is calcareous, perforate, and with varying degrees of rugosity, but usually only faintly so. The umbilicus is deep and rather wide. Aperture is interiomarginal, opening into the umbilicus and often covered by a plate-like extension of the final chamber. About 95 percent of the studied specimens coil dextrally. The holotype measures 0.43 mm. in length, 0.36 mm. in breadth, and 0.26 mm. in thickness.

Remarks.—The flattened spiral side with rapidly expanding chambers will best serve to distinguish this species from others of the genus.

This new species is very similar to *Globotruncana helvetica* Bolli, 1945. Bolli (U. S. Natl. Mus. Bull. 215, 1957, p. 56) mentions such transitional forms he observed in material from Tunisia. It lacks the typical keel of the genus *Globotruncana*, however, although the occasional nature of the spiral side of the latter few chambers indicates a close relationship, and, while the spiral side is flattened as a whole, each individual whorl is rounded in section as opposed to the flattened nature of those of *G. helvetica* as shown by the cross sections of the original types.

R. praehelvetica differs from *R. kingi* (a new species also described in the present paper) by the chambers that rapidly increase in size, and by the flattened spiral side. Although the inner whorls are raised above the outer whorl, they are in a step-like manner and do not display the evenly convex nature of *R. kingi*.

Additional paratypes—UCLA no. 26681.

Occurrence.—The holotype is from Member II, Middle Turonian, locality 20, on Salt Creek, about 1600 feet east and 2300 feet south of the NW corner of sec. 3, T32N, R3W, east of Redding, Shasta County, California. This is one of the most abun-

dantly occurring species that is found only in Member II.

Genus GLOBOTRUNCANA Cushman, 1927
GLOBOTRUNCANA CANALICUTATA (Reuss), *sensu stricto*
Pl. 50, figs. 1a–c

Rosalina canaliculata REUSS, 1854, K. Akad Wiss. Wien, Math.-Naturw. Cl. Denkschr., Bd. 7, p. 70, pl. 26, fig. 4.

(*?*)*Globigerina canaliculata* EGGER, 1900, K. Bayer Akad. Wiss., Math.-Naurh. Abt., Abh., Kl. 2, v. 21, pt. 1, p. 172, pl. 21, figs. 15–17, 24–26.

(*non*) *Globotruncana canaliculata* CUSHMAN, 1927, Cushman Lab. Foram. Research, Contr., v. 3, p. 116, pl. 23, fig. 11; WHITE, 1928, Jour. Paleontology, v. 2, p. 282, pl. 38, fig. 3; CUSHMAN, 1932, *idem*, v. 6, p. 343, pl. 51, fig. 14; CUSHMAN & DEADERICK, 1942, Cushman Lab. Foram. Research, Contr. v. 18, p. 65, pl. 15, figs. 23–27; CUSHMAN, 1944, *idem*, v. 20, p. 14, pl. 3, fig. 8; CUSHMAN & GOUDKOFF, 1944, *idem*, v. 20, p. 62, pl. 10, fig. 10; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 149, pl. 61, figs. 17,18; ——, 1949, *idem*, 221-A, p. 10, pl. 4, figs. 20,21; ——, 1949, Maryland Dept. Geology, Mines and Water Resources, Bull. 2, p. 265, pl. 25, fig. 22; BANDY, 1951, Jour. Paleontology, v. 25, p. 509, pl. 75, fig. 2; FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rpt. Inv. no. 22, p. 128, pl. 20, fig. 21.

The shape of the test of *Globotruncana canaliculata* is rotaloid, almost circular, strongly compressed, very little inflated, spiral side almost flat, elevated only slightly in the middle, and showing two whorls that rapidly increase in width. Edge is broadly truncate, with a deeply depressed furrow. There are six to eight chambers in the ultimate whorl, that on the spiral side are rather wide, arcuate, and surrounded by an elevated rim, while on the umbilical side they appear triangular, "with a central depression and surrounded by a raised rounded rim that is highest around the umbilicus." Sutures are distinct (on the umbilical side perfectly straight, radial, and depressed). The surface of the wall has a spiny covering. The umbilicus is wide. (Aperture is interiomarginal, opening into the umbilicus.) All specimens of this study coil dextrally. The hypotype measures 0.55 mm. in length, 0.49 mm. in breadth, and 0.17 mm. in thickness.

Remarks.—The above description is a direct translation from the German text of Reuss. A look at the holotype figure will show that his referral to depressed chambers on the umbilical side (the present writer has placed the quotation marks) in the text is an obvious description of a specimen with collapsed chambers. He did not give a description of the sutures or aperture, but they are clearly shown on the figure to be as given above.

Except for a few questionable instances in which the figures are very poor or only the spiral view given, previous authors have mistakenly referred their specimens to this species. Most of these should have been referred to *G. linneiana* (d'Orbigny) = *Rosalina linneiana* d'Orbigny, 1839. Bronniman & Brown (1955, p. 542) regard *G. canaliculata* as conspecific with *G. linneiana*. Obviously, this view cannot be based on observation of the holotype illustration. The most nearly unique characteristic of *G. canaliculata* is the completely straight, depressed, and radial pattern of the sutures on the umbilical side, which will serve to distinguish it from the above named and similar species with curved and tangential sutures.

That the edge is double-keeled is borne out by the description "edge broadly truncate, with a deeply depressed furrow," although an edge view illustration was not given. Of the six specimens from the Redding area, two have the keels widely spaced on all chambers, two—one of which is illustrated—have the keels converging and close together on the last chamber, while the other two have the keels close together, almost appearing as one, on the last three chambers. The umbilical and spiral views are almost exact replicas of Reuss' illustration—two of the specimens even have collapsed chambers—and there is no doubt that these should be referred to this species.

Occurrence.—Studied specimens are from Member IV, Coniacian. The original types were from the Turonian and/or Lower Senonian of Salzburg, Germany.

GLOBOTRUNCANA HELVETICA Bolli
Pl. 50, figs. 2a–c

Globotruncana helvetica BOLLI, 1945, Eclogae Geol. Helv., v. 37 (1944), no. 2, p. 226, pl. 9, figs. 6–8, text ill. 1 (9–12); SIGAL, 1952, 19th Congr. Géol. Internat., Monogr. Reg., Ser. 1, No. 26, p. 31, fig. 32; HAGN & ZEIL, 1954, Eclogae Geol. Helv., v. 47, no. 1, p. 30, pl. 3,

fig. 1; BOLLI, 1957, U. S. Natl. Mus. Bull. 215, pl. 13, fig. 1; p. 53 (chart).

The shape of the test of *Globotruncana helvetica* is rotaloid, spiral side almost flat with two or three whorls visible and the inner whorls often slightly raised, while the umbilical side is strongly inflated. The periphery is lobulate, edge broadly rounded, and with a distinct keel around the spiral side. There are five to six chambers in the final whorl that are hemispherical in shape and increase rapidly in size. Sutures are curved on the spiral side, depressed and almost radial on the umbilical side. The wall is calcareous, perforate, with the surface rugose, especially on the umbilical side. The umbilicus is deep and wide. Aperture is interiomarginal, opening into the umbilicus. All of the specimens of this study coil dextrally. The hypotype measures 0.61 mm. in length, 0.49 mm. in breadth, and 0.29 mm. in thickness.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The species is found in all but the uppermost part of the Turonian in Trinidad. The original types are from the Lower Turonian, on the crest of the Säntis Range, Canton St. Gallen, eastern Switzerland. The range of the species in the type area is from the Lower Seewerkalk to lowermost Upper Seewerkalk (Lower-Upper Turonian), and the referrals of the range into the Upper Cenomanian are rather questionable, as the Seewerkalk is generally considered as Turonian, and quite certainly the uppermost Lower Seewerkalk should be no older than Lower Turonian.

GLOBOTRUNCANA LINNEIANA (d'Orbigny)
Pl. 49, figs. 8a–c

Rosalina linneiana D'ORBIGNY, 1839, in Ramon de la Sagra, "Histoire physique, politique et naturelle de l'ile de Cuba," A. Bertrand, éditeur, Paris, p. 101, v. 8, pl. 5, figs. 10–12. (For complete synonymy, see Catalogue of Foraminifera).

Globotruncana lapparenti BROTZEN, 1936, Geol. Unders., Avh., Ser. C, no. 396 (Arsbok 30, no. 3), p. 175,176; pl. 1, figs. 1–4, 7; pl. 2, fig. 2; pl. 6, figs. 2,3; pl. 8; pl. 9, figs. 2,3, 6; tf. 1, tf. 2, not figs. I and J; tf. 3.

Globotruncana lapparenti subsp. *lapparenti* BOLLI, 1945, Eclogae Geol. Helv., v. 37 (1944), no. 2, p. 230, pl. 9, fig. 11; p. 234, tf. 1 (15–16).

Globotruncana canaliculata FRIZZELL, 1954, Bureau Econ. Geol., Texas Univ., Rpt. Inv. no. 22, p. 128, pl. 20, fig. 21 (See *G. canaliculata* above of the present paper for all synonymies marked (*non*) *G. canaliculata* that should be referred to *G. linneiana.*)

Globotruncana linneiana BRONNIMAN & BROWN 1955, Eclogae Geol. Helv., v. 48, p. 540, pl. 20, figs. 13–15 (Neotype), 16,17 (Topotype); pl. 21, figs. 16–18.

(Direct translation of the type description from the French text of d'Orbigny): "Test suborbicular, very depressed, periphery bicarinate, a trifle concave on the underside, strongly umbilicate, but without an umbilical disk; the surface very rugose. Spire slightly elevated, well marked by the borders of the chambers; composed of three whorls, the first of which is in part masked by the rugosity. Chambers compressed, numbering six in each whorl, oblong, flattened on the under side; oblique, completely bordered by a rim; on the under side they are particularly bordered on the outer and umbilical sides, but the rims are less distinct than on the upper side. Aperture upon the edge of the chambers within the umbilicus.

"By the bicarinate periphery, by the flattened chambers on both sides, by the strong rims even about the umbilicus, this species is distinguished from all others in a way so strongly contrasting that it cannot be confused with any existing species."

About 95 percent of the specimens of this study coil dextrally throughout the stratigraphic range of the species. The hypotype measures 0.43 mm. in length, 0.35 mm. in breadth, and 0.19 mm. in thickness.

Remarks.—D'Orbigny was quite optimistic in writing the final phrase of his description above. Unfortunately, many later workers have confused his with other species. No doubt this was brought about by the hesitance to refer Upper Cretaceous specimens to this species that was originally reported from the Recent beach sands of Cuba. Bronniman & Brown (1955, p. 540–542) in their discussion of this species point out that it was derived from nearby Upper Cretaceous strata and designate a type locality, a neotype (the whereabouts of the holotype is unknown), and illustrate the latter as well as a topotype and another specimen.

The illustration of the holotype shows the chambers to be collapsed. It is not natural for the chambers of such a foraminiferal test to be concave in the center with raised edges, and so they must have collapsed after

burial. This is a common occurrence among fossil foraminiferal tests, although most of the early workers did not take it into account when writing their descriptions. One may easily see that, considering this, the umbilical side would be somewhat more inflated than is shown by the illustration. From topotype material, Bronniman & Brown show one topotype with parallel sides, while the neotype is definitely biconvex. The Redding specimens show this same range in variation throughout the stratigraphic range of the species.

All the American specimens that have been incorrectly referred to *G. canaliculata* are within the range of variation and should be assigned to this older species. With the exceptions noted in the synonymy above, all of the original illustrations of *G. lapparenti* Brotzen and *G. lapparenti* Brotzen subsp. *lapparenti* Brotzen, emend. Bolli are also within the range of variation of *G. linneiana* as shown by topotype material (although Bronniman & Brown did not consider this so) and as indicated by the present study. There would be a worthwile value in dividing this species and recognizing the latter named species on the basis of greater convexity if the stratigraphic ranges were different. The range of both species is identical (Turonian-Campanian), they are alike in all other respects, and, therefore, the two latest named should be considered junior synonyms of *G. linneiana* (d'Orbigny).

Occurrence.—Studied specimens are from Member II, Middle Turonian, Member IV, Coniacian, and Member VI, Santonian. The holotype is from Recent beach sand derived from Upper Cretaceous strata, on the east bank of Rio Martin Perez at Habana Bay, Cuba.

GLOBOTRUNCANA RENZI Gandolfi
Pl. 50, figs. 3a–c; 4a–c

Globotruncana renzi GANDOLFI, 1942, Riv. Ital. Pal., v. 48, Supp., Mem. 4, p. 124, pl. 3, fig. 1; pl. 4, figs. 15,16,28,29; pl. 10, fig. 2; p. 124, tf. 45; HAGN & ZIEL, 1954, Eclogae Geol. Helv., v. 47, no. 1, p. 37, pl. 3, fig. 2.

(*non*) *Globotruncana renzi* BOLLI, 1957, U. S. Natl. Mus. Bull. 215, p. 58, pl. 14, fig. 3; p. 53 (chart).

The shape of the test of *Globotrunacana renzi* is rotaloid, biconvex, with two and one-half to three whorls visible on the spiral side. The periphery is lobulate, and the edge has a closely spaced double keel on the early chambers of the final whorl, becoming single on the last and occasionally the penultimate chambers. There are five angular chambers in the final whorl, that increase rather rapidly in size. Sutures on the spiral side are curved, raised, and beaded, while on the umbilical side they are depressed and curved. The wall is calcareous, perforate. The umbilicus is shallow and wide. Aperture is interiomarginal, opening into the umbilicus. All the specimens of this study coil dextrally. The hypotype measurements are: Plate 50, figure 3—0.56 mm. in length, 0.44 mm. in breadth, and 0.27 mm. in thickness; Plate 50, figure 4—0.49 mm. in length, 0.42 mm. in breadth, and 0.22 mm. in thickness.

Remarks.—This species has a similar stratigraphic range in California and Europe. Bolli (1957, p. 53) shows the range in Trinidad as being Coniacian and Lower Santonian. His figure of the hypotype and description is of a specimen with the sutures of the initial whorls depressed and the spiral side very irregular. This is not at all indicated by the holotype illustrations which show all the sutures on the spiral side distinctly raised and the side regularly convex. Except for the character of the keeled edge, Bolli's specimen is quite different, and if the stratigraphic range in Trinidad is based on similar specimens then the authenticity of the presence of *G. renzi* in the Coniacian and Santonian is highly questionable.

Some of the Redding specimens have the last one or two chambers on the umbilical side projecting rather far as shown in Plate 50, Figure 4. There is a continuous sequence between these and the very typical specimens as exemplified by Plate 50, Figure 3.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The species is reported from the uppermost Cenomanian and lower Turonian of Europe, and is found in the Lower and Middle Turonian in the western Sacramento Valley, California. The original types were from the Lower Turonian in the region of Chiasso, Canton Ticino, southeastern Switzerland.

GLOBOTRUNCANA SCHNEEGANSI Sigal
Pl. 49, figs. 9a–c

Globotruncana schneegansi SIGAL, 1952, Congr. Geol. Internat. XIX, Monogr. Régionales,

Ser. 1 (Algeria), no. 26, p. 33, fig. 34; HAGN & ZEIL, 1954, Eclogae Geol. Helv., v. 47, p. 37, pol 5, fig. 12; BOLLI, 1957, U. S. Natl. Mus. Bull. 215, p. 58, pl. 14, fig. 1; p. 53 (chart).

The shape of the test of *Globotruncana schneegansi* is rotaloid, biconvex, with two and one-half to three whorls visible on the spiral side. The periphery is lobulate, and edge with a distinct single keel. There are five to six angular chambers in the final whorl. Sutures on the spiral side are curved, raised, and beaded, while on the umbilical side they are curved and depressed. The wall is calcareous and perforate. The umbilicus is shallow and wide. Aperture is interiomarginal, opening into the umbilicus. All the specimens of this study coil dextrally. The hypotype measures 0.54 mm. in length, 0.39 mm. in breadth, and 0.21 mm. in thickness.

Occurrence.—Studied specimens are from Member II, Middle Turonian. The species occurs in the Lower Turonian in Europe, and in the Turonian and Coniacian of Trinidad. The original types are from the Lower Turonian, and while the type locality was not designated, it is probably in northern Algeria.

Family HETEROHELICIDAE Cushman, 1927

Genus HETEROHELIX Ehrenberg, 1841

HETEROHELIX GLOBULOSA (Ehrenberg)

Pl. 50, figs. 10a,b

Textularia globulosa EHRENBERG, 1840, K. Akad. Wiss. Physik. Abh. (Jahrg. 1838), p. 135, figs. 2,4,5,7,8.

Gümbelina globulosa (Ehrenberg), in CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 105, pl. 45, figs. 9–15. (See this reference for complete synonymy to 1946.)

Heterohelix globulosa (Ehrenberg), *in* MONTANARO GALLITELLI, 1957, U. S. Natl. Mus. Bull. 215, p. 137, pl. 31, figs. 12–15.

The shape of the test of *Heterohelix globulosa* is small, rapidly tapering, one and one-half to two times longer than broad, greatest breadth near the apertural end, with lobulate periphery and edge broadly rounded. Chambers are spherical, rapidly increasing in size, arranged biserially throughout or with the initial ones coiled or tending to coil. Sutures are distinct, depressed, at only a slight angle with the longitudinal axis. The wall is calcareous, finely perforate, and smooth. Aperture is a high arch with distinct lips at the inner base of the final chamber. The hypotype measures 0.25 mm. in length, 0.18 mm. in breadth, and 0.12 mm. in thickness.

Remarks.—Very few specimens were found in the samples from Member IV, and, of these, many tend to coil in the initial portion. Montanaro Gallitelli (1957, p. 137–138) presents a fine discussion of the genera *Gümbelina* and *Heterohelix*, with evidence for regarding the former as a junior synonym of the latter, which she does, and as has been done in the present paper.

Occurrence.—Studied specimens are from Member IV, Coniacian. The species is very widely distributed throughout most of the Upper Cretaceous and Paleocene of Europe and the Americas. The original types were from the Cretaceous, but Ehrenberg did not designate a type locality, only reporting the occurrence in Denmark and England.

Genus TUBITEXTULARIA Sulc, 1929

TUBITEXTULARIA cf. T. CRETACEA (Cushman)

Pl. 50, figs. 9a,b

Rectogümbelina cretacea CUSHMAN, 1932, Cushman Lab. Foram. Research, Contr., v. 8, p. 6, pl. 1, figs. 11,12.

Tubitextularia cretacea MONTANARO GALLITELLI, 1957, U. S. Natl. Mus. Bull. 215, p. 143, pl. 33, figs. 4,5.

The shape of the test of *Tubitextularia cretacea* is elongate, and slender. Chambers are biserial and globular in the initial portion, while in the adult part they are uniserial, subglobular to pyriform, slightly overlapping, and with the last chamber extended to form a tapering neck. Sutures are distinct, and depressed. The wall is smooth and very finely perforate. Aperture is circular, at the end of the tubular neck. The hypotype measures 0.36 mm. in length, 0.10 mm. in breadth, and 0.07 mm. in thickness.

Remarks.—The very small, rare specimens are only tentatively referred to this species, as the biserial chambers are not as globular as in the holotype. Only a few broken specimens were found. In some respects they also resemble *Loxostoma minutissima* Cushman.

Occurrence.—Studied specimens are from Member IV, Coniacian. The holotype of *T. cretacea* is from the Maestrichtian Arkadelphia clay, northeast of Hope, Arkansas.

Family PLEUROSTOMELLIDAE Reuss, 1860

Genus PLEUROSTOMELLA Reuss, 1860

PLEUROSTOMELLA GREATVALLEYENSIS Trujillo, sp. nov.

Pl. 50, figs. 5a–c, 6a,b

The shape of the test of *Pleurostomella greatvalleyensis* is elongate, straight, round or oval in transverse section, increasing rapidly initially, and with the sides nearly parallel in the adult portion. The chambers are distinct, overlapping, inflated except in the earliest part, triserially arranged initially, quickly becoming biserial, and in the completely developed adult the last few are staggered uniserial with the final chamber much longer proportionately. The sutures are flush and narrowly limbate initially, becoming depressed and non-limbate in the adult. The wall is calcareous, finely perforate, and smooth. The aperture is formed by a crescentic opening with a slit extending downward, somewhat resembling an anchor in shape, at the top of a hooded depression on the upper side of the final chamber. The holotype measures 0.65 mm. in length, and 0.22 mm. in diameter; the illustrated paratype 0.32 mm. in length, 0.21 mm. in breadth, and 0.18 mm. in thickness.

Remarks.—The uninflated initial chambers, inflated later chambers, and more importantly, the anchor shaped aperture will distinguish this new species from all others.

The somewhat rare juvenile specimens as portrayed by the illustrated paratype that had not yet attained staggered uniseriality somewhat resemble several previously described species, but differ primarily in the shape of the aperture. There is a continuous sequence between these and those like the holotype. Many gerontic specimens were also found in which the final one or two chambers are distorted by being flattened in a plane parallel to the crescent-shaped part of the aperture.

Additional paratypes.—UCLA no. 26692.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner of sec. 35, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member IV, Coniacian, as well as from other localities in Member VI.

PLEUROSTOMELLA SUBNODOSA Reuss

Pl. 50, figs. 7a,b

Pleurostomella subnodosa REUSS, 1860, K. Akad. Wiss. Wien, Math.-Naturw. Cl., Sitzber. Bd. 40, p. 204, pl. 8, fig. 2; CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 132, pl. 55, figs. 1–9. (See this reference for complete synonymy to 1946.)

The shape of the test of *Pleurostomella subnodosa* is elongate, tapering from a blunt initial end to the greatest breadth near the apertural end, and nearly round in transverse section. Chambers are staggered uniserial throughout, or with initial few biserially arranged. Sutures are distinct, depressed, and oblique. The wall is calcareous, finely perforate, and smooth. Aperture is nearly terminal, at the side of the last chamber, in a hooded depression. The hypotype measures 0.69 mm. in length, 0.18 mm. in breadth, and 0.14 mm. in thickness.

Occurrence.—Studied specimens are from Member IV, Coniacian, and Member VI, Santonian. The species is reported widely from the Upper Cretaceous of Europe and the Americas. The type horizon and locality was not designated by Reuss, but he gave occurrences as in the Cenomanian?, Turonian, and Senonian of Germany, Poland, and Bohemia.

Genus NODOSARELLA Rzehak, 1895

NODOSARELLA WINTERERI Trujillo, sp. nov.

Pl. 50, figs. 8a,b

The shape of the test of *Nodosarella wintereri* is short, straight, round or oval, or occasionally compressed parallel to the length of the aperture to form an acute edge, and with the greatest breadth near the middle of the final chamber. Chambers are few, seldom more than four, inflated, strongly overlapping, the last one proportionately much longer, and increasing rather rapidly in size following the bluntly rounded initial chamber. Sutures are distinct, depressed, non-limbate, and normal to the longitudinal axis of the test. The wall is calcareous, finely perforate, and smooth. Aperture is a crescent-shaped opening with two teeth protruding from the lower side, and is distinctly hooded, situated in a small depression at the upper side of the ultimate chamber. The holotype measures 0.71 mm. in length, 0.36 mm. in breadth, and 0.31 mm. in thickness.

Remarks.—The few, strongly overlapping, inflated chambers and crescent-shaped aperture with two teeth will serve to distinguish this species from others of the genus.

The specific name is in honor of Dr. Edward L. Winterer, professor of geology, University of California, Los Angeles.

Additional paratypes.—UCLA no. 26695.

Occurrence.—The holotype is from Member VI, Santonian, locality 90, on the south bank of gully tributary of Old Cow Creek, about 2000 feet east and 800 feet north of the SW corner of sec. 35, T32N, R2W, east of Redding, Shasta County, California. Other studied specimens are from Member IV, Coniacian, as well as from other localities in Member VI.

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BIOSTRATIGRAPHY AND THE NEW PALEONTOLOGY

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ABSTRACT—The increasing acceptance of the concept of a species varying in time, comparable to the geographic variation of species, alters the entire nomenclatural basis of biostratigraphy. Biostratigraphers must reorient their basic concepts to those of correlating samples from supplies that represent some unknown segments of the biological continuum. Biostratigraphers cannot continue to use taxa (species) of the "New Paleontology" for smaller biostratigraphical units because they are not sufficiently refined to meet the need for detail in modern and future stratigraphy.

INTRODUCTION

"Perhaps more than anything else, it is this, the comparison of vertical with horizontal variation, that deserves the appellation the 'New Paleontology'" (Sylvester-Bradly, 1956.)

ONLY recently have Darwinian concepts been completely accepted by most paleontologists; evolution has been professed, but its precepts have not entered into paleontological practice, particularly among invertebrate paleontologists. The reasons for this slow acceptance are many, would require lengthy explanations, and some are reasonable, some unreasonable (Wilson, 1958). With the gradual acceptance, not just profession, of evolution, the concept of the species in paleontology is changing. This change immediately enables the paleozoologist to study evolution, paleoecology, and other branches of paleobiology with greater ease than heretofore. On the other hand, it destroys the nomenclatural basis for biostratigraphy, and biostratigraphers, if they do not find new methods, will at least have to reorient and reevaluate the basic thinking behind their techniques. Cooper (1958) indicates a large amount of inadequate paleontology has been published by stratigraphers not properly founded in biology. While agreeing with Cooper, I would also like to add that likewise a great bulk of haphazard stratigraphy has been published by paleozoologists untrained in the basic techniques and precepts of stratigraphy. Paleontology is neither biology nor geology, but the field of overlap between them, just as chemistry and geology overlap in an area of study we call geochemistry. It is essential to paleobiology and to stratigraphy that the paleontologist be well trained in each of the two disciplines, not in one to the partial or complete exclusion of the other. After the fundamental training, he may concentrate in one field or the other, or in both, but the fundamentals of both fields are basic to each. I have omitted any reference to "purely" physical stratigraphers at this point; some paleontology is basic to all stratigraphy and certainly the following remarks on "gradualism" and "evolution" are just as pertinent to physical stratigraphers as to biostratigraphers.

This is particularly true because the problem facing the new generation of biostratigraphers arises from the increasing general acceptance of the work of Huxley (1940, 1943) and Simpson (1940, 1944). A short resume of the history of stratigraphy, zoological nomenclature, and evolution will readily explain why there is a problem.

HISTORICAL SUMMARY

The history of biostratigraphy can be summed up in the names of three men: (1) William Smith, who recognized that certain fossils were particular to certain strata; (2) Alcide d'Obigny (1840–1860), who demonstrated that some biologic units were not always restricted to particular types of rock, but instead crossed rock boundaries; and (3) Albert Oppel (1856–1858) who gave the zone its present biostratigraphic concept by using the zone only as long as its distinctive fossil or fossils could be found, but who also gave the zone its present chronostratigraphic concept by making it a subdivision of a stage. All later work has

been concerned with the refinement of basic principles. I have assumed the fundamental concept of superposition included by Teichert (1958b) in his historical summary. I am not concerned in this paper with the origin of ideas; my references are to those who are most responsible for their general acceptance. Thus d'Orbigny has directly influenced invertebrate biostratigraphy more than Cuvier and other catastrophists.

Our systems of taxonomy and nomenclature can be laid at the feet of one man, Carl Linné. Since his publication of the "Systema Naturae", all further taxonomic and nomenclatural work that has been accepted has been concerned with the refinement of his basic system.

The history of the concept of evolution cannot be summed up in so few words. Wendt (1956), Irvine (1955), and Eiseley (1958) have entire books largely concerned with this problem. Many men prepared the way for Charles Darwin, and to quote Irvine (1955), "In short Darwin muddled into genius and greatness like a true Englishman". As Wilson (1958) points out, "Survival of the fit" did not explain the rectilinear (Simpson, 1944) patterns of evolution which the late 19th century and early 20th century paleontologists observed or thought they observed (Simpson, 1944). Only when modified with the modern genetics concept of the "gene pool" could there be a return to Darwin and his "Survival of the fit". Thus, only recently have paleontologists, who always believed in evolution, accepted Darwinian evolution. Consequently it is only since the general acceptance of Simpson's syntheses (1940, 1944) and Huxley (1940, 1943) that Darwin can have a really telling effect on biostratigraphy. It is yet much too soon to predict the results.

THE CONFLICT OF BASIC CONCEPTS

In order to understand the change that is occurring or about to occur in biostratigraphy, it is necessary to back track again and analyze some of the basic concepts on which the subject is based. The only intact basic concept is superposition, and it need not be further considered here. First, we must take up the work of d'Orbigny and d'Orbigny's teacher, Georges Cuvier. By d'Orbigny's standards Cuvier was only mildly catastrophic. In his "Cours Elementaire" d'Orbigny (1852) published the Cuvierian concept of world-wide catastrophies: 27 world wide catastrophies forming the boundaries between 28 world wide stages, the stages grouped together into terrains. The date of this publication is only six years earlier than the 1858 reading of Darwin and Wallace before the Linnean Society; certainly d'Orbigny must have heard rumors of Darwin's studies! However, he was not even influenced by Lyell (1834 and other editions). The 27 catastrophies upon which stage (and terrain) nomenclature was originally based contain no hint of either a biological continuum or a sedimentational continuum, but instead, contain their antithesis. Each of the stage boundaries was a time plane representing a world wide catastrophe. Theoretically if d'Orbigny had found two groups of fossils that looked alike, one above a stage boundary and the other below, each group would have received a distinct name because it was incompatible with the catastrophic concept for a species to cross the boundary. Zittel (1901) and Dunbar & Rodgers (1957) emphasize the catastrophism of d'Orbigny, and if some think that I make too much of a whipping boy of him, this is of course for effect. However, an analysis of five volumes of d'Orbigny (1840–1860) demonstrates, I believe, the great catastrophist, especially if one considers the scale of nomenclature and taxonomy a century ago. I ignore many of d'Orbigny's fossils in this analysis because the age ranges he gave were not always couched in stage terms and would require an interpretation. In the cephalopod volume, d'Orbigny had not yet named the Upper Cretaceous stages; his meaning is quite obvious, but to avoid any chance interpretation I have omitted those fossils for which he does not designate the stage by name.

Of the 107 cephalopod species analyzed, not one exceeded a single stage; of 325 gastropod species analyzed none exceeded a single stage in range; of 165 species of brachiopods, two species of *Terebratula* are listed as occurring in more than one stage; of 492 species of pelecypods, only 15 are listed in more than one stage; and of 250

species of echinoids, none exceeded a single stage in range. In total the ranges of 1339 invertebrate species were examined. Of these, 17 were listed as ranging across stage boundaries. I doubt if such close adherence of species ranges and stage boundaries could be duplicated at present, even with modern taxonomic splitting.

It should be emphasized that later biostratigraphers, although professing to a belief in evolution, practiced catastrophism, because when they found a new fauna, or a new assemblage, instead of revising stage boundaries, they named a new stage; until at last, in the Jurassic alone, more than 126 different stage names had been proposed (Arkell, 1956). Such practices are not compatible with Darwinian evolution nor are they compatible with gradualism as preached by Lyell.

The creation of a completely new set of species with the advent of each new stage, following a world-wide catastrophe, agreed well with the other aspect of biostratigraphy for which we have to examine the early history—that is, the Linnéan species. The Linnéan species was an unchangeable entity, specially created, and disappearing not by transformation, but only by death of the race—accompanying a complete obliteration of life, in the post-Cuvierian sense of catastrophism; these species were unalterable, unrelated entities.

Thus, when biostratigraphy was born, the two prevailing concepts among early biostratigraphers were catastrophism and the immutable, specially created species. By using the Linnéan and Cuvierian classifications, biostratigraphy had been prejudiced until more modern concepts could not break down the barrier. The entire development of the concept with all its variations is too lengthy to present here; besides, Eiseley (1958) discusses the problem splendidly.

Most of us no longer believe in catastrophe, excepting Schindewolf (1953), although because Schindewolf raised pertinent questions we should, perhaps, reexamine the entire concept. On the other hand, Schindewolf catastrophism and Cuvierian catastrophism have nothing in common because Schindewolf retains his in the framework of evolution, if not neoDarwinian evolution. Most of us likewise no longer believe in the immutable species. In other words, although we use Cuvier's classification, we no longer profess the basic precepts that resulted in his classification. It is interesting that Cuvier's influence was like a law in France. Not only was he successful for many years in making a scientific laughing stock of those bold men who were discovering fossil man in France (Wendt, 1956), but his influence was so great that as late as 1852 d'Orbigny could publish the ultimate in catastrophism, 18 years after the appearance of the third edition of Lyell's "Principles" (1834). Even though Hutton's uniformitarianism had even earlier laid the ground work for the "gradual" hypothesis, it was Lyell who really applied uniformitarianism and gradualism to geologic processes (Eiseley, 1958) so that it became possible to believe in a theoretical, at least, sedimentational continuum. The nearest thing to this in France was Prevost's "facies" concept, but he thought of facies only within a terrain (Teichert, 1958a). The application by most American geologists (Teichert, 1958a) of facies changes only to time equivalent strata is really a holdover from catastrophism; it is unacceptable in evolution or gradualism.

Certainly, now, many geologists believe it possible that at some places sedimentation was always in progress, so that if all the localities were known, the sedimentational record would be relatively complete. Any attempt to measure time by thickness of sediments, or salinity of the sea, was dependent on a concept of sedimentation continuum. This theoretically complete record is the sedimentational or rock continuum, and, although not stated therein, the concept is compatible with the material in Lyell's "Principles of Geology". It is incompatible with d'Orbigny's "Cours Elementaire", published many years later.

The concept of a biological continuum is not so easily laid at the feet of one, or even a few men. Even Linné recognized that some species were more closely related than others, and that some species were even difficult to distinguish from others. Consequently, he repudiated his own scheme of nomenclature and classification (Wendt, 1956), but could not convince other natu-

ralists that it should be discarded. Eiseley (1958) does not make as bold a statement as Wendt, probably because he is a scientist instead of a journalist, but even Eiseley indicates that today we use the Linnéan system without its author's blessing.

Degree of relationship between species, then, was a concept of Linné by 1770. Other men had similar concepts, undoubtedly, but were afraid to express them for fear of losing their heads, especially after the experience of Buffon. Various forms of evolution (the biological continuum) were considered by Buffon, Erasmus Darwin, Lamarck, and others (Wendt, 1956; Irvine, 1955; Eiseley, 1958). Inasmuch as Lyell (1834) and others had already discussed "the struggle for existence", the credit for the theory of evolution, like the rock continuum an opposite of catastrophism, is given to Charles Darwin because he gave it body, form, and the practical emphasis of empirical data—and "the survival of the fit".

WHAT IS BIOSTRATIGRAPHY?

The effect of the concept of a biological continuum on biostratigraphy can be discussed more easily after determining the purpose of biostratigraphy. The work of the paleontologist is twofold: (1) to trace the various paths of the biological continuum (the courses of evolution) and thus build up a picture of the "tree of life". This means that the paleozoologist, as a figurative individual contrasted with the biostratigrapher, is concerned with building a taxonomic structure the branches of which are parallel to the direction of evolution; and evolution has only one direction, time. If his tree of life is to be valid, the paleozoologist must have great confidence in the boundaries between the branches. He is building the phyletic, natural, or so-called "vertical" classification. (2) The biostratigrapher, on the other hand, is interested in dividing the sedimentary continuum into as many segments as possible, and he is thus interested in building a taxonomic structure which will emphasize the boundaries between these segments of the rock continuum, boundaries which extend at directions presumably at a right angle to the direction of evolution. The more accurate the stratigraphy, the greater the biologic refinement, and the greater the necessity for devising methods which supply excellent confidence limits between different segments of the rock continuum. This is the "artificial" or so-called "horizontal" classification. That one and the same classification may be "horizontal" to one paleontologist and "vertical" to another emphasizes the semantic overtones of a problem not just semantic but basically involving different types of thinking, and other even more intangible factors.

To summarize, the purposes of the biostratigrapher and the paleozoologist are antithetical, the paleozoologist dividing the biological continuum in one direction and the biostratigrapher dividing the rock continuum in a different direction. Unfortunately, by precedent and common language the paleozoologist and the biostratigrapher have to use the same biological units. Hence the recent rash of articles concerning "Paleontologist, biologist or geologist".

Let me emphasize again the figurative nature of paleozoologist and biostratigrapher as used here. They often appear in conflict in one paleontologist, and then result in the inconsistencies in attitude that occur in classification in his different papers. A fine example of such inconsistencies because of this conflict appear in L. F. Spath's (1923–1943) "Monograph of the Ammonoidea of the Gault", in which the degree of description of morphospecies changes from one group of ammonites to another as Spath's views see-sawed back and forth over the 20 year period during which he serialized this monograph.

To further summarize, the biostratigrapher must classify a rock continuum by means of a biological continuum, using a stratigraphic nomenclature and biologic nomenclature that were originally applied to a lot of unrelated, discontinuous entities. Darwin figuratively supplied us with the biological continuum which we still classify by Linnéan nomenclature.

DARWINISM AND BIOSTRATIGRAPHY

The recent effect of Darwinism on biostratigraphy is the result of paleozoologists'

trying to fill the biological continuum. Although few of them will accept Burma's (1948) definition of a species as "a segment of a continuum", each of them in practice actually argues that a species thought of in any other way is not compatible with concepts of evolution and modern genetics. If this were not true, paleozoologists would not object so strenuously to the morphospecies of biostratigraphers. If one believes in evolution, then any phyletic grouping of animals or plants can only be a segment of the biological (evolution) continuum, and theoretically the continuum must be filled with segments, not only that join, but were evolved one from the other.

In order to discuss more easily the impact of the modern species concept (The New Paleontology of Sylvester-Bradley, 1956), I wish to define a species from three different points of view. Although these categories have been used by others (*e.g.*, Cain, 1954), I do not wish to embarrass them by attributing my definitions to them.

1. *Biospecies.*—(the geographic species of neontologists). A biospecies is usually composed of one or more populations, either interbreeding or potentially interbreeding. Most neontologists will allow paleontologists to use the biospecies if their paleobiospecies vary morphologically as known neontological biospecies are known to vary and if the paleobiospecies differ from other paleobiospecies as known and comparable neontological biospecies differ from each other.

The biospecies is a geographic thing to modern neontologists. From the standpoint of a few evolutionists, it is a tremendous gene pool from which those individuals which have the best combination of genes (another way of saying that they are best adapted to their environment) are selected—Darwin's survival of the fit. However, most neontologists have been as slow to accept a species variable in time as have biostratigraphers, and Newell (1956) points out the general concept that a population consists of only one generation. However, if a population consists of only one generation, then genetic drift and gene replacement are impossible in a population and only possible in a succession of interbreeding populations, each a generation consisting of the offspring of the preceding population. On the other hand, if a population is a geographically variable unit that consists of many related successive generations in time, it is a basic unit which can be discussed and in which gene replacement and drift can proceed. But temporal variation has been added, and such a population can no longer be expected to maintain the same statistical parameters as the single generation population, except for the normal distribution, which will be characteristic of any continually sampled undirected segment of the biological continuum, no matter what its size, although the kurtosis and dispersion may vary.

2. *Morphospecies.*—(generally the species of the biostratigraphers). The morphospecies is here defined as any group of fossils which differ morphologically from other fossils in the same genus, and which occupies a certain level, the word level usually being applied by neontologists who have not learned to be wary of the term. "Level" is the word which lends suspicion to this definition, and paleozoologists who use this definition assume that a level is an instant in geologic time; they further assume, then, that if a sample is collected from this "level" and treated statistically, it will have the same parameters of variability as a sample from a Recent population. I have tried this with gastropod samples from the middle Albian, and although a normal distribution curve can be obtained as it can in populations, the coefficient of variability ranges as high as from 12 to 20, even on the most conservative characters. Unfortunately empirical data for the coefficient of variability in recent gastropod populations is not available. I suggest that these Albian gastropod samples represent many successive, evolving populations, and that the statistical parameters are not only different from, but do not even approach those for a single population; distribution based on the normal curve is at best a poor criterion because the normal distribution is possible in many combinations of living things (Simpson & Roe, 1939) that are not populations, and is particularly possible in samples continuously distributed through a succession of evolving populations, although in the latter the curve may be less leptokurtic, and the dispersion may be greater. The distribution

curve loses its practical value when the record becomes so nearly complete (see Newell's diagram, 1956) that a continuum, or even a segment of a continuum, of such curves has to be interpreted. It works in practice only because of the incomplete record.

The morphospecies fails conceptually because it denies evolution, even though the paleontologists who use morphospecies pay homage to a belief in evolution, and some of them would emphatically deny that they are using morphospecies; the exceptions are those paleontologists who use form taxa because they do not know the affinity of the fossils, because they do not know the function of the parts that make up the fossils, or because they do not know which part belongs with which part. Whether a particular taxon is a morphospecies or a paleobiospecies is, with some taxa then, a matter of individual belief, or, perhaps, more often of no concern because its author did not even bother with the problem.

3. *Chronospecies.*—(a category that is generally unused except as a language term by which to convey ideas). Chronospecies are arbitrary morphological segments on temporal clines of the biological continuum —in other words a succession of morphospecies, but probably not grading into each other because of incomplete rock continuum (Newell, 1956) or unfossiliferous layers. Sometimes the record is more nearly complete and we have intergrading chronospecies, the older having evolved into the next younger (Trueman, 1924; Rowe, 1899; Carruthers, 1910); the validation of such phenomena is rare (Wright, 1958). Only in examples such as these would I be willing to accept orthochronology (Teichert, 1958b) as validated.

The neontologist or paleozoologist who accuses a colleague of using chronospecies thinks that those chronospecies are much smaller categories, such as Burma's (1954) breeding group 2, than are the neontological biospecies, and that several chronospecies should be lumped together into a biospecies, to produce a taxon that is geographically variable and variable in time. The fallacy here is the first assumption; the assumption that lumping a bunch of morphospecies or chronospecies produces something that gives the same variability as a neontological biospecies is not empirically confirmed, although various authors write as though it were; confirmation is neither negative nor positive, largely because of sampling problems of fossils, and because of the assumption by paleozoologists or neontologists that a level, an instant in time, at right angles to the direction of evolution, can be collected. The assumption that one can obtain samples so that geographic variation can be computed against time variation is extremely dangerous to biostratigraphic concepts and to evolutionary concepts because the data obtained by making the assumption are then immediately used to prove the assumption.

FACING UP TO THE PROBLEM

Since the biostratigrapher is losing the battle of the species, and rightly so or we would have to admit that Darwin and evolution were still not a part of basic paleontological concepts, what is the future program of the biostratigrapher? Darwin and evolution have really not reached biostratigraphy yet, as demonstrated by the moderate catastrophism of Dunbar & Rodgers (1957) and the more extreme catastrophism of Moore (1958); by the mildly (Cuvierian) catastrophic work of Lochman & Wilson (1958) to the extreme catastrophism of Loeblich & Tappan (1957); and by almost all other biostratigraphic papers. Unless authors are explicit, the reader cannot differentiate catastrophist from evolutionist because in no publications can an evolutionary concept be demonstrated by biostratigraphic classification, terminology, or language. Had I written papers of the same format I am certain I would say the same thing about my own papers; Teichert (1958b) emphasizes the basic contribution of the concept of evolution to biostratigraphic zonation and correlation, but to Teichert only biostratigraphic units of world wide empirical [and homotaxial] validity should be called zones. That their validation is empiricism belies their evolutionary basis, even though they would not exist were it not for past evolutionary processes. Sylvester-Bradley (1951b) inadvertently demonstrates on Carruthers' (1910) data that the nomenclature alone

has nothing to do with the concepts and that it cannot express evolution. Even Sylvester-Bradley's idea cannot be expressed by taxonomic names, but must be accompanied by discussion and diagrams. The time for a change in biostratigraphic thinking is not coming, it is already past.

Nearly all biostratigraphers and paleozoologists profess a belief in Darwinian evolution of some kind, but no biologic classifications and no biostratigraphic classifications actually express that belief at the level of the lower taxa. It is true that the arrangement of any text book of zoology or paleontology can be said to reflect the concept of evolution, and I have often told those who criticize the teaching of evolution that the subject cannot be dodged, because it is implicit in any modern zoology textbook; on the other hand about the only taxonomic change from an advanced "scale of being" concept or progressionism (Eiseley, 1958) is the recent removal of the Echinoderma to a position between Arthropoda and Prochordata. Maybe it is not even possible to express concepts of evolution by taxonomy and nomenclature devised for catastrophic and special creation concepts. Most authors, in their writings, do not consider the effect of Darwinism on their techniques or on their results. Their real thinking on the subject remains hidden unless they express it in writing. Teichert (1958b) is one of the very few to state his opinions clearly concerning evolution and biostratigraphy. This leads one to the conclusion that he may be one of the very few to have a clear opinion.

If the anachronistic nomenclature and taxonomy are incapable of expressing evolution, then the biostratigrapher must devise techniques that include concepts of evolution and express these concepts. Lacking such techniques, he should express his considered opinion. How many existing biostratigraphic techniques involve in their application the basic concept of evolution?

TECHNIQUES OF BIOSTRATIGRAPHY

1. *Simple symbols for biostratigraphic taxa.*—Some paleozoologists and neontologists have suggested that biostratigraphers should number or letter their morphospecies so that nomenclatorally they would not be confused with "proper" biospecies. This has been done for other reasons by economic micropaleontologists, and *Marginulina 19* or *Nodosaria 7* still retain a definite meaning to some of the older hands on the Gulf Coast of the United States. Numbers, letters, and other simply symbolic designations have never been successful. One reason is because they lack the mnemonic aid and individuality of a personal and unique name. Gradualism or evolution is not basic to their use, and the statement attributed to Linné (Eiseley, 1958, p. 15) that:

> "the first step of science is to know one thing from another. This knowledge consists in their specific distinctions; but in order that it may be fixed and permanent distinct names must be given to different things, and those names must be recorded and remembered"

is just as true now as it was 200 years ago.

2. *Statistical correlation.*—Correlation by identifying like or similar quantitative parameters on populations from different areas has been suggested as a proper biostratigraphic technique. I use the word population with distrust, but that is the word used by proponents of this scheme; I am certain that many neontologists would be really concerned if they actually knew how the meaning of populations has been distorted by some paleozoologists. *Supply* (Treloar, 1951) would be a better term for this purpose. Apparently statistical correlation has been applied with success in the few examples in which it has been tried, but it requires superior collections. In all my ammonite collections, except one, I do not have a sample sufficiently well preserved and large enough to produce the desired confidence limits; the exception consists of samples from the San Carlos area of Trans-Pecos Texas, but there are no other samples with which to correlate these.

People who recommend this technique are not faced with the problem of describing or redescribing 300 to 400 species in the next 10 years. Furthermore, although Newell (1956) and Simpson & Roe (1939) emphasize the quantitative importance an individual fossil may have to the hypodigm and the concept of the species to which it belongs, from the standpoint of quantitative methods in biostratigraphy the individual fossil is meaningless. The evolution concept

is basic to this technique only because the concept was developed to satisfy a need by paleozoologists who were conscious of the incompatibility of evolution and other techniques. But the samples to be correlated by this method must be large enough and sufficiently well preserved to produce refined confidence limits.

3. *Assemblage correlation.*—Assemblage correlation is the common biostratigraphic technique. It is not sufficiently refined for most detailed work, and in this day and age of specialists there are few paleontologists capable of diversified assemblage identification. If I interpret Cooper (1958) correctly, he hopes that the day will come when specialists in different groups work together on common correlation problems. When I now see a list of fossils from many phyla, identified by one individual, I become very suspicious of its validity. Furthermore, there is great danger of correlating environment when correlating assemblages, because most assemblages begin and end at any one locality because of environmental conditions. For this reason I cannot completely agree with the concept of orthochronology as outlined by Teichert (1958b), even though I use similar zones consistently and continually. In correlating pelagic assembalages there is furthermore a great danger in the negative correlation, which consists of not correlating two sets of strata because their pelagic assemblages differ. By this I mean a definite statement that the two sets of strata are of different age. An example of this is the statement (Adkins, 1929, 1933) that the San Carlos beds are of Taylor age. This statement was made not because the San Carlos beds contain Taylor pelagic assemblages of ammonites, since the Taylor ammonites were and are still unknown, but because they do not contain any Austin pelagic assemblage of ammonites. The San Carlos beds correlate with part of the Austin (Young, 1959), and the different pelagic ammonite assemblages result from different environments of deposition. Assemblage zonation involves faunal superposition if homotaxial assemblages are used, but evolution is not a basic concept to this technique.

4. *Appearances and disappearances.*—Correlation may be made by appearances and disappearances; this is similar to correlating by teilzone or topozone (Moore, 1957). Unless the succession is homotaxial there is no meaning to appearances and disappearances because most appearances and disappearances are basically environmental. This is a different application of range-zonation concepts (Hedberg, 1958), and means only that the appearance, or disappearance, or teilzone, is within that ill-defined thing called a biozone. Unfortunately Hedberg's idea that most correlation is "biozone" correlation is probably true, and illustrates one of the great defects in biostratigraphy—the lack of refined techniques. If homotaxial successions of appearances, disappearances, or topozones are found so often that an empirical body of data is built up so that one expects to find them in the same arrangements the next time, they become useful, but still, the exception should always be expected the next time a section is measured or studied. Furthermore, superposition is a basic concept to this technique of correlation; evolution is not.

5. *Transition zones between chronospecies.*—The zone where one chronospecies is changing into another chronospecies should be a good zone with which to correlate. More simply this is the zone of overlap of specific characters, one set of characters typical of the younger species which is descended from the older species with another set of characters. Such transition zones are not often found, and their rarity emphasizes the incompleteness of the rock continuum and adds suspicion to any work based on appearances or disappearances. Evolution is certainly basic to this technique, but the transition is, unfortunately, usually based on single characters, and therefore not typical of the "New Paleontology".

6. *Individual occurrences.*—Rough correlations can be made by individual occurrences. In correlating between rocks which represent different environments and in which the assemblages are mutually exclusive, only rough correlations can be made on the rare (accidental) occurrence of a pelagic fossil buried out of its environment. This is probably the only biostratigraphic correlation that can be made under such conditions, and it can never be very exact. Evolutionary concepts have nothing to do with this technique.

7. *Correlating segments of the continuum.*—

This technique is used unknowingly by some biostratigraphers. If the paleozoologists and neontologists are correct in assuming that morphospecies and chronospecies are not biospecies, then according to the new paleontology (Sylvester-Bradley, 1956) the biostratigraphers are using only segments of the continuum for their work. More logical and real however is the impact of economic geology leading to this technique among micropaleontologists who are well founded in biology and the "new paleontology"; they realize, or suspect, at least, that the taxa they use for correlation do not compare with neontologic biospecies. These workers knowingly use a dual standard, talking and publishing on one kind of species (which we can call a biospecies) and working with a different kind of species (which we can call a morphospecies or a chronospecies); the latter are the smallest segments of the continuum which they can devise and still work within proper limits of confidence for refined stratigraphic purposes. Burma (1954) would probably consider such units to be segments of his type 2 breeding groups. Sylvester-Bradley (1956) has earlier mentioned this dual standard demanded of the same paleontologist for two different types of work and Spath (1923–43) in part 14 of the "Gault Monograph" and in his paper on the Jurassic cephalopod fauna of Kachh (1933) discusses the necessity of the dual standard in paleontology; however, I feel that Spath discussed his collections in terms of species rather than in terms of samples. Whatever names are applied the dual standard is necessary, but frustrating.

Although the concept of evolution is not basic to this technique, the dual standard technique is a direct result of a realization of the meaning of evolution to concepts of paleontological nomenclatures and taxonomy and the resulting effect on biostratigraphy.

8. *Guide fossils.*—Although guide fossils are still used in correlating the guide fossil concept is not consistent with the "new paleontology". To be useful, and then only in a certain restricted area, a guide fossil is a sedimentary accident, important and meaningful only if sedimentation and environmental conditions produced an epibole which can be walked out and its stratigraphic importance determined empirically. The concept of evolution does not enter into this technique.

9. *Lineage correlation.*—This subject would probably be called orthochronology by Teichert (1958b). Teichert includes orthochronology under biostratigraphy, whereas Jeletzky (1956) includes it under time-stratigraphy, without using the term, but Jeletzky does not believe in the use of the term biostratigraphy. The term orthochronology is unfortunate because the "chronology" ending indicates that an interpretation has been made. To me part of the change from biostratigraphy to time-stratigraphy is the change from the objective to the interpretation of the objective. Regardless of the terminology there is a biostratigraphic technique that is based on proved evolutionary lineages. I refer again to such papers as those by Rowe (1899), Newell (1942), Carruthers (1910), and Trueman (1924). Such examples are rare (Wright, 1958), and are probably better known in terrestrial vertebrates than in invertebrate animals.

Developing and describing these lineages, as these writers have, could not have been done without the evolutionary concept. It would have been impossible, for example, for d'Orbigny to have written one of these papers. However, it does not follow that the paleontologist who next correlates with a species from one of these lineages believes in evolution. He may not have even heard of the word, although this is not probable in 1959. It is my opinion that most paleontologists are seldom even aware of the concept of evolution when they use fossils for biostratigraphic purposes.

I have not used orthochronology because I believe it involves interpretation, and also because Teichert (1958b) would include under orthochronology some world wide zones, such as the Mesozoic ammonites, in which there is a world wide homotaxial faunal superposition, but in many of which the lineages have not yet been traced out and validated [contrast Reyment (1958) with Wright (Arkell, Kummel and Wright, 1957) and (Matsumoto, 1955)]. Zuckerman (1954) has emphasized that "views on phylogeny are never more than inferences, drawn in the light of the geological timescale, that are based on an assessment of the resemblances and differences between or-

ganisms, living and extinct." Furthermore, Garstang's (1922) views cast doubt on any paleontologic phylogeny that does not consist of a complete temporal cline of adult individuals from one end of the supposed phylogeny to the other end. Assemblage zonation is undoubtedly, if we believe in evolution, the result of past evolutionary processes, but the real basis for the correlation is not evolution, it is the body of empirical information concerning the homotaxial arrangement of zones.

SUMMARY

Listed above are most of the techniques of biostratigraphy that have been tried, but they probably do not represent all the available possibilities. They constitute most of the techniques that will continue to be used. In other words there is no simple, single solution that will solve the problems of the biostratigrapher faced with the taxonomy for the "new paleontology", which in reality is a technique of classification imposed by a realization of the meaning of Darwinian evolution.

The only precaution that the biostratigrapher can take, and even self-styled paleozoologists do not yet always take this precaution, is to realize that he is not working with species, but is working and correlating with samples. This is the reason that I advocate the term supply (Treloar, 1951) in place of population; it is less prejudicial to paleontological thinking. Burma (1954) has pointed out that there is no such thing as a real species—that a species is not objective. Newell (1956) and Sylvester-Bradley (1951a; 1956) have both argued for the objectivity of the species, even referring to Sylvester-Bradley's (1951a; 1956) neither inapt nor impertinent, but none the less not pertinent, comparison of the species with the twig on a tree; according to Sylvester-Bradley the twig is objective, and since the species is a part of the tree of life, it is likewise and just as objective. Of course, all true twigs on real trees end at bifurcations, and the twig is identified by the bifurcations at each end. The only subjective decision is how small is a branch and how large a twig. If all species ended at bifurcations the work of the paleontologists would be much easier, but usually the paleontologist does not even know how the species ends or begins. However, to describe a species from a few samples is like trying to describe a twig on a few molecules. We can obtain the variation, perhaps even a normal distribution of more abundant and less abundant molecules—or a distribution curve on the size of the molecules, but we cannot easily obtain the shape, length, or diameter of the twig by taking a few biopsies and examining the molecule samples. Likewise, with the paleobiospecies we can get the variation, or at least a decent estimate thereof by examining samples, but we cannot obtain its shape in time, or space, and this latter is the meat of evolution.

A species is an interpretation of a sample of a population or populations, or samples of populations; more simply and accurately a sample from a supply (Treloar, 1951). The samples are quite objective, but this does not make the species any more objective. Quantitative approaches merely refine the techniques, and they should be enthusiastically supported, but they do not make the species one whit less an interpretation. I do not object to the paleobiological approach to the species—to the new paleontology; it is a necessary derivation of neo-Darwinian evolution. I do object to the unrealistic attempts to make the species objective; this is exactly what the typologists have tried to do, and the paleozoologists should object most vociferously.

In summary it would seem that the biostratigrapher, in the future, must realize that he is not correlating species, nor even comparing species; he is comparing samples, and 99.9 percent of his samples cannot be assumed to be from single populations. The good biostratigrapher must remain objective and therefore must concern himself with comparing the objective—the samples, no matter what nomenclature he applies to them.

Such a procedure will not change the terminology with which we are saddled; it merely means more rigid adherence to separating the objective from the interpretative, rather than confusing the two. Not only must the economic biostratigrapher educate himself, but he must educate his administrative superiors so that they will understand that by maintaining such a rigid

pattern of thinking he is increasing the probability of more accurate answers; let me repeat, not increasing the accuracy, increasing the probability of accuracy. Many economic micropaleontologists and a few macropaleontologists are now using this approach, but their superiors certainly do not understand the thinking behind their employees' work.

The ideas presented here have benefited immeasurably from countless discussions with numerous paleontologists, and particularly from discussions with my colleagues. I wish to thank W. C. Bell, Ed W. Owen, E. L. Lundelius, and John A. Wilson for reading the manuscript and for their many suggestions and criticisms.

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PENNSYLVANIAN SPORE FLORAS FROM THE WARRIOR BASIN, MISSISSIPPI AND ALABAMA

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ABSTRACT—A study of macerated coals from three wells in Mississippi which penetrated the Pennsylvanian section indicates that spores, which are potentially useful in correlation from one area to another, can be isolated from regular well cuttings. No definite correlations can be made between the coals from the three wells and the outcrop samples from Walker County, Alabama, on the basis of the spore assemblages of the coals chosen for this study, but spores present in the Alabama and Mississippi samples indicate that all the coals are Pottsville in age. The spores present in the lowermost coals of the Young-Henderson well provide information extending the stratigraphic range of several genera farther into the lower Pennsylvanian in North America. This information corresponds in most cases with information published by Potonié & Kremp (1954) from Europe and Asia.

INTRODUCTION

THE study of the spore floras from outcrop samples of Pennsylvanian coals of Alabama and from the well cuttings of three wells which were drilled through the Pennsylvanian system in Mississippi was initiated with several objectives in mind.

First, it was desirable to find out whether or not regular samples from rotary drill cuttings contained enough coal to provide sufficient isolated spores to make any correlation between the various wells. The use of rotary well samples for spore studies is not new (Kosanke, 1950; Taylor, Pullen, Sims & Payne, 1944), but in most previous cases special coal samples were taken. In this study only regular samples were used, and these had been split tó a very small size so that the coal present in any one sample was commonly less than one gram.

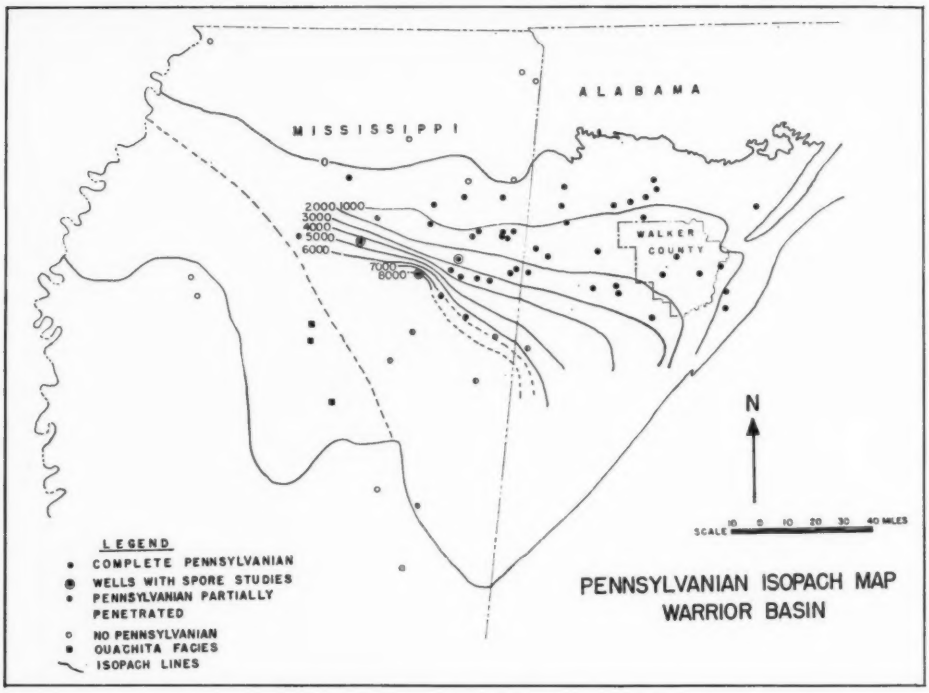
Another aim was to study outcrop samples from Alabama to determine where they could be placed in the Pennsylvanian section of Mississippi.

A third aim was to determine how sections of Pennsylvanian coals from Alabama and Mississippi would correlate with a known area such as the Illinois Basin on the basis of spore assemblages from the coals. Another objective was to place some sort of age determination on the Alabama and Mississippi sections; that is, determine whether the sections are entirely equivalent to the Pottsville, or whether other Pennsylvanian rocks are also present.

Even if the well cuttings failed to yield sufficient information for correlation, it was felt that the study would make a contribution to the existing paleobotanical information on the lower Pennsylvanian since most northern Appalachian coals of the same stratigraphic position are of high rank and not amenable to maceration studies. Furthermore, the only published data on spores from the Warrior Basin is in a paper by Hoffmeister, Staplin & Malloy (1955) in which they discuss the ranges of Paleozoic plant spores in North America. They included identifications of spores from selected coal beds in Alabama.

All spores which were obtained from the coals in this study were first identified generically. Later spores of known stratigraphic significance in Illinois as well as other obvious long-ranging species were identified. No effort was made in this study to identify all previously described species, but rather to obtain a general survey of the distribution of genera.

This study is based on a thesis prepared for the Master of Science degree, University of Illinois, 1956. The writer gratefully acknowledges the guidance of R. M. Kosanke for instruction in spore studies and aid in interpretation of the findings of this study. H. R. Wanless introduced and advised the study. Thanks are given to the Carter Oil Company, Shell Oil Company, the Union Producing Company, the Sunray Oil Company, the United States Geological Survey,



TEXT-FIG. *1*—Pennsylvanian isopach map of the Warrior Basin. Samples for this study were obtained from the three wells indicated by circle dots in Mississippi and from the area in and around Walker County, Alabama, which is outlined on the map. Isopach information by H. R. Wanless.

and to the Illinois State Geological Survey for their help.

GEOLOGICAL SETTING

During the past 10 to 12 years drilling in Mississippi has shown that the Paleozoic rocks of the Warrior Basin, which crop out in Alabama, extend into Mississippi where they are overlapped by Cretaceous sediments (Mellen, 1947). Well records indicate that deposition in the Mississippi part of the basin may have been greatest during the Paleozoic.

In Mississippi the basin can be divided into belts, the most northern of which contains pre-Pennsylvanian sediments. Farther south, wells have penetrated the Pennsylvanian from a feather-edge thickness to a total of more than 8000 feet in the Union Producing Company's Young-Henderson No. 1 well. As shown in Text-figure 1, which is an isopach map of the Pennsylvanian system in the Warrior Basin, there is a tremendous thickening of the Pennsylvanian section in the basin. South of the 8000-foot interval in Text-figure 1, wells have entered the Pennsylvanian section but have not completely penetrated it. In this belt, the rocks of the Pennsylvanian have been drilled to more than 4000 feet, and it is possible that the 8013 feet of Pennsylvanian rocks that have been recorded from the Young-Henderson well is not the maximum thickness of Pennsylvanian sediment in the basin.

Farther south, two wells in Mississippi and one in Alabama have entered Ordovician strata below the Mesozoic close to other wells which enter the Pennsylvanian section below the Mesozoic, thereby suggesting a thrust fault in that area. Whether Pennsylvanian rocks lie beneath the Ordovician section or whether there is a shaper and rapid upturn is not known. On the south and southwestern flanks of the basin, wells have penetrated deformed slaty shale of the

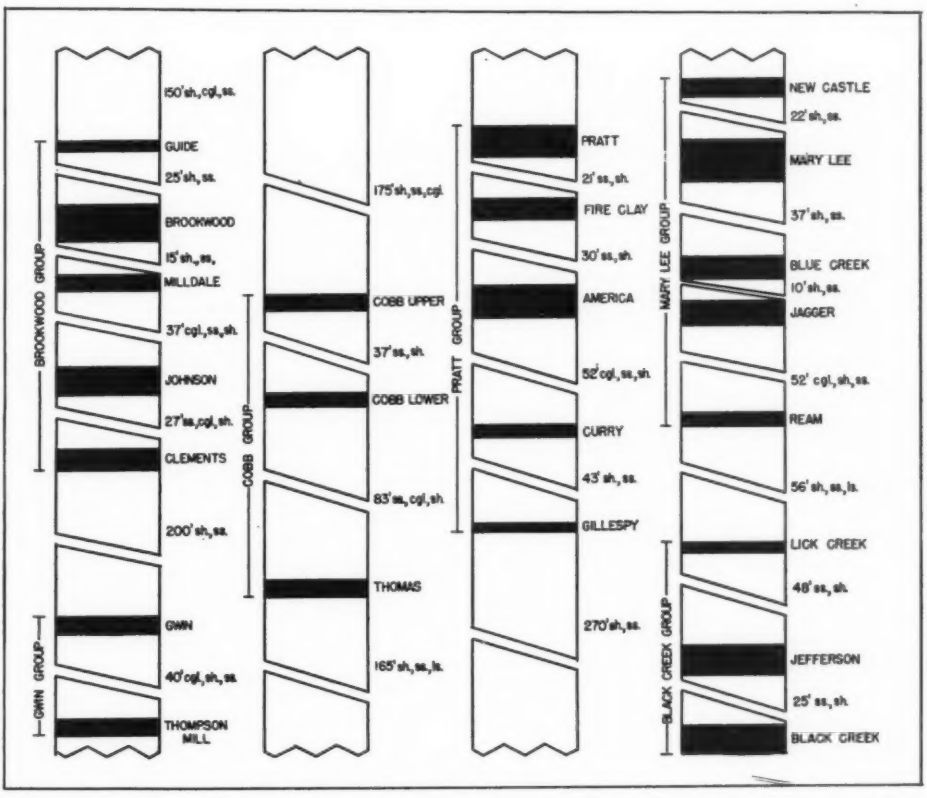
Ouachita facies. These wells are illustrated in Text-figure 1 by black squares. West of this belt two wells have been drilled which have encountered igneous rocks. Since no wells drilled to the east have reported encountering the Ouachita facies, it is suggested that this facies pinches out eastward or is cut out by thrusting.

In the middle belt of the Warrior Basin there is a tremendous thickening of Pennsylvanian rocks in the area where there has been complete penetration of the Pennsylvanian. This is well illustrated by the proximity of the 8000-foot isopach line to the 3000- and 4000-foot lines. The Pennsylvanian section thickens 4000–5000 feet in a distance of only 8 miles.

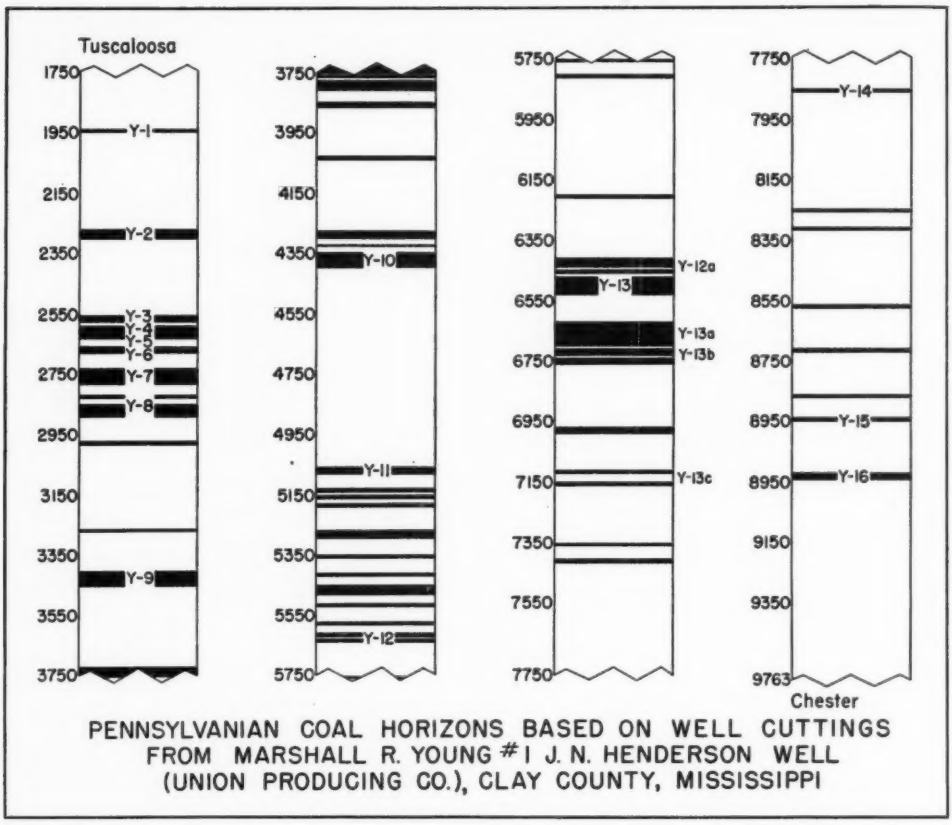
LOCATION OF SAMPLES

Walker County, Alabama, where the outcrop samples were obtained, and the three wells in Mississippi from which the well-cuttings were obtained are shown in Text-figure 1. The Union Producing Company's Marshall R. Young #1 J. N. Henderson well was drilled through 8013 feet of Pennsylvanian strata in Clay County. The Carter Oil Company's John W. Crane well penetrated 4736 feet of Pennsylvanian rocks in Calhoun County. The Shell Oil Company's Feazel #1 Lee Harrington well penetrated 2105 feet of Pennsylvanian rocks in Monroe County.

Text-figure 2, adapted from McCalley (1900), shows the general section of the coals in the Warrior Basin above the Black Creek Coal. In this study the coals of the Pratt, Mary Lee, and Black Creek Groups were macerated and the spore assemblages of the coals studied. The Ream Seam, the



TEXT-FIG. 2—General section of the coals above the Black Creek Seam, Warrior Basin (adapted from McCalley, 1900). Thicknesses indicated are mean thicknesses of Pennsylvanian strata in the basin.



TEXT-FIG. 3—Pennsylvanian coal zones in the Young-Henderson well. Sample intervals which were macerated are indicated by Y-1, Y-2, etc.

basal coal of the Mary Lee Group, is divided into three seams, the Lower, Middle, and Upper Ream.

Text-figure 3 shows the various portions of the Pennsylvanian section which yielded coal in the study of the Marshall R. Young #1 J. N. Henderson well. It was this well that gave the most satisfactory paleobotanical data. Fifty-four coal zones were recognized, and no doubt many more exist since it is possible that some of the coal zones illustrated in Text-figure 3 represent a mixing of two or more coal beds. Of the coal zones located in the well, 20 were macerated and yielded spores.

Coal zones were fewer in number in the Carter Oil Company well and were practically absent from the Shell Oil Company well. This may have been related to sampling procedure as well as by the marked decrease in Pennsylvanian sediments in these two areas.

Electric logs of the Young-Henderson well show 96 possible coal zones, many of which correspond to the approximate level where coal was found in the rotary samples. The slight discrepancy in the level where coal is found and the level where it should be found according to electric log data can be explained by the time lag of the cuttings in reaching the surface.

PREPARATION OF SAMPLES

In the preparation of the coal from the well cuttings for maceration, the coal was first separated from other rock fragments by the use of CCl_4 (sp. gr. 1.58) in which coal floats while other rock fragments sink. The

coal was macerated by using the method described by Kosanke (1950) with slight modifications. The coal is first oxidized with Schulze's Solution (one part concentrated aqueous solution of $KClO_3$ and two parts of cold concentrated HNO_3). After washing the oxidized coal with water, a 10% KOH solution is added to disperse the humic matter. At this point the insoluble botanic ingredients such as spores and cuticle are recovered from the residue.

Since the samples of the well cuttings were very small, they were not screened as were the larger outcrop samples from Alabama. The outcrop samples were screened on a 65-mesh (210 microns) Tyler screen and the plus 65-mesh material stored. The minus 65-mesh material from the outcrop samples and the entire sample from the well cuttings were treated identically after this step of the preparation.

After the residue was thoroughly washed free from the soluble humic matter, it was stained with safranine Y, the water was removed by dehydrating repeatedly in alcohol, and the residue containing the spores was mounted in diaphane.

The portion of the residue not used in the preparation of slides has been stored at the Illinois State Geological Survey.

With the hope of obtaining additional paleobotanical information about parts of the section in which coals were not present, shales were macerated using hydrofluoric acid. The samples from the well cuttings which were treated in this manner failed to yield enough additional data worth reporting.

RESULTS OF SPORE STUDIES

From the 20 levels in the Young-Henderson well, 16 previously described spore genera have been identified (Text-fig. 4). A determination of the abundance of genera at the particular levels was made, but this information reveals the abundance only for the sample prepared and is not thought to be a valid indicator for the entire coal bed. The numbers 1, 2 and 3 in Text-figure 4 indicate the relative abundance of the genera in each particular level.

Lycospora is the most abundant genus in 16 of the 20 levels examined, *Laevigatosporites* is most abundant in two levels, and

	Y-1	Y-2	Y-3	Y-4	Y-5	Y-6	Y-7	Y-8	Y-9	Y-10	Y-11	Y-12	Y-12a	Y-13	Y-13a	Y-13b	Y-13c	Y-14	Y-15	Y-16	
CALAMOSPORA	X	X	X	3	X	X	X	X	X		X	X	X		X		X		X	3	
CIRRATRIRADITES	X	X	X	X	X	X	X	X	X	X							X		X	X	
DENSOSPORITES	X		X	X		X	X	X	2	X	3	3	3		X				X	X	
ENDOSPORITES	X	X	X	X	X	X	X	X	2	3	X	X			X		X	X	3	2	
FLORINITES	X	X	X	X	X	X	X	X	X	X	X	X					2	X	X	X	
GRANULATISPORITES	X	X		X	X	X	X	X	X	X	X				X		X	X	X		
LAEVIGATOSPORITES	2	1	2	2	1	2	X	2	3	2	2	2	X		3		X	X	X	X	
LYCOSPORA	1	2	1	1	2	1	1	1	1	1	1	1	1	1	1		1	2	1	1	
PUNCTATISPORITES	X	X	X	3	X	X	2	3	2	X	3	3	2	2	2	X	3	1	2	X	
RAISTRICKIA	X	X	X	X		X	X	X	X		X	X							X	X	
REINSCHOSPORA								X													
RETICULATISPORITES	X	X				X		X	X									X			
SCHULZOSPORA										X								X	X	X	
SIMOZONOTRILETES								X													
TRIQUITRITES	X			X	X		X	X	X		X	X			X				X		
WILSONIA								X					X								
NEW GENERA						X		X											X	X	

TEXT-FIG. 4—Stratigraphic distribution of spore genera from Young-Henderson well. Relative abundance indicated by 1, 2, and 3.

Punctatisporites is the most abundant genus in one level. One zone, Y-13b, yielded only one spore, *Punctatisporites*, and therefore no abundance figures are given for this zone.

The fact that *Laevigatosporites* is present in all layers in the Young-Henderson well except Y-13 and Y-13b was surprising because of the fact that most previous information from the United States indicated that this genus was rare or absent from Mississippian and lowermost Pennsylvanian deposits (Kosanke, 1950; Potonié & Kremp, 1954; Hoffmeister, Staplin & Malloy, 1955). *Laevigatosporites* is present in the basal four layers in the well, although it is rare in all four of them.

The stratigraphic implications of the study of the spores from coals located in the Young-Henderson well are as follows: Sample Y-1, the uppermost coal found (Text-fig. 3), contains species which indicate that the coal is upper Tradewater or Pottsville in age. These species include *Densosporites sphaerotriangulatus*, *Granulatisporites pallidus*, *Punctatisporites quaesitus*, *Cirratriradites maculatus*, and *Raistrickia crocea*. All these species occur in coal beds of the Eastern Interior Basin in upper Tradewater or earliest Carbondale coals (Kosanke, 1950). In the northern Mid-Continent, Eastern Interior Basin, and eastern Appalachian region, *Densosporites* has been reported to occur in coal beds at approximately equivalent positions up to theTradewater-Carbondale boundary of the Eastern Interior Basin. Thus, it appears that the top sample, Y-1, is upper Tradewater or upper Pottsville or lower Allegheny in age.

In the basal sample, Y-16, no upper Mississippian guide spores such as *Tripartites*, *Rotaspora*, *Auroraspora*, or *Grandispora* were observed. This information in itself is not too important because the amount of coal sample which was available for maceratiln may not have been representative of the entire coal zone. Of more importance is the fact that *Laevigatosporites* does occur in this level and above. This information would definitely indicate that the age of the coal is Pennsylvanian and would be in accord with published information from Europe by Potonié & Kremp (1954), by Hoffmeister, Staplin & Malloy (1955), and from published data of the Illinois Geological Survey (Kosanke, 1950).

From the 15 coal beds of the Pratt, Mary Lee, and Black Creek Groups which cropped out in the area in and around Walker County, Alabama, 12 previously described spore genera have been identified (Text-fig. 5). No attempt was made to determine the abundance of genera in each coal bed.

The spore assemblage obtained from the maceration of the Mary Lee Coal was very poor, only five spore genera being obtained from the outcrop sample. The sample was subjected to two maceration attempts and was closely checked during the maceration process, but no additional genera were observed. It is suggested, therefore, that the lack of spores in this coal sample is due to the sample itself, not to any errors in the maceration technique.

The most important finding in the outcrop samples is the complete absence of *Laevigatosporites*, a form present in the Illinois Basin from upper Caseyville throughout the rest of the Pennsylvanian coals and also present in every level macerated from the Young-Henderson well in which enough spores were found to be meaningful.

Schulzospora is more abundant in the coals macerated from the Pratt and Mary Lee Groups than in coals from the Black Creek Group. *Schulzospora* is not present in the Young-Henderson well until level Y-10 and is not found in any two adjacent coal zones until the bottom three samples of the Young-Henderson well.

Cirratriradites, which is present throughout most of the Young-Henderson well, is present in only one sample of the Alabama outcrop samples, the Middle Ream Coal.

On the basis of *Schulzospora* found in the outcrop samples, it can definitely be said that the coals of the Pratt, Mary Lee, and Black Creek Groups are lower Pottsville in age. (Kosanke, 1950; Hoffmeister, Staplin & Malloy, 1955).

In an attempt to correlate the outcrop samples from Alabama with the coals sampled from the Young-Henderson well, it was found that there are two places where the outcrop section could fit into the Young-Henderson section. Since the coals from Alabama lack *Laevigatosporites*, it is most logical to place the entire outcrop section below Y-16, the lowermost coal found in the Young-Henderson well. This explanation would best take care of the complete lack

	PRATT GROUP							MARY LEE GROUP								BLACK CREEK GROUP	
	PRATT	FIRE CLAY	AMERICA	CURRY	GILLESPY	NEW CASTLE	MARY LEE	BLUE CREEK	JAGGER	UPPER REAM	MIDDLE REAM	LOWER REAM	LICK CREEK	JEFFERSON	BLACK CREEK	
CALAMOSPORA		X	X	X		X	X	X	X	X	X	X				
CIRRATRIRADITES										X						
DENSOSPORITES	X		X		X	X		X	X	X	X	X	X	X	X	
ENDOSPORITES						X		X								
FLORINITES			X				X			X	X			X	X	
GRANULATISPORITES	X		X		X	X		X	X	X	X	X	X	X	X	
LAEVIGATOSPORITES																
LYCOSPORA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
PUNCTATISPORITES	X	X	X	X	X	X	X	X	X		X		X	X	X	
RAISTRICKIA	X		X			X				X						
RETICULATISPORITES								X	X							
SCHULZOSPORA	X	X		X	X	X	X	X	X		X		X			
TRIQUITRITES			X					X			X				X	

TEXT-FIG. 5—Stratigraphic distribution of spore genera from Walker County, Alabama, outcrop samples.

of *Laevigatosporites* in the outcrop samples. Poor samples, perhaps vitrain layers which are deficient in spore content, should be considered as possible explanation for the lack of *Laevigatosporites* in Y-13 and Y-13b, the two samples which did not contain *Laevigatosporites*. In general, *Laevigatosporites* decreases in relative abundance in the lower portion of the Young-Henderson well section, and it has previously been reported (Kosanke, 1950) that *Laevigatosporites* is not present in the spore assemblages of lowermost Pennsylvanian coals of Illinois.

The only other possible correlation of the outcrop samples with the Young-Henderson section is attempting to place the outcrop section between two of the sample intervals of the Young-Henderson well. The deficiency in *Laevigatosporites* in the outcrop samples could then be explained as equivalent to a zone in the Young-Henderson well which contains no *Laevigatosporites*. However, this is considered rather unlikely since it would be logical to assume that the part of the Pennsylvanian section which is approximately 700 feet thick in Alabama would be expanded into a far greater thickness in Mississippi. It is also considered unlikely that a genus as abundant as *Laevigatosporites* throughout the section would be missing from one of the unsampled intervals.

In the Carter well, only five coal zones were found. Nine previously described genera were observed (Text-fig. 6). The C-1 level, the uppermost coal zone in the well, yielded species of spores which have affinities to the species present in the top of the Young-Henderson well. *Raistrickia crocea*, which was found in both levels C-1 and C-4, indicates that the Pennsylvanian section penetrated in the Carter well corresponds to the top of the Young-Henderson well. In the latter, *Raistrickia crocea* is found in much more abundance in the upper part of the well than in the lower.

The Shell well contained only one coal sample which yielded spores; only five genera were found in this level, S-1 (Text-fig. 6). The absence of coal in this section indicates that either the Pennsylvanian coals

	C-1 2560'-2660'	C-2 2930'-2980'	C-3 2980'-3010'	C-4 4610'-4650'	C-5 5690'-5710'		S-1 2030'-2040'	
CALAMOSPORA	X	X			X		X	
CIRRATRIRADITES		X						
DENSOSPORITES					X			
GRANULATISPORITES	X	X		X			X	
LAEVIGATOSPORITES	X				X		X	
LYCOSPORA	X	X	X		X		X	
PUNCTATISPORITES	X	X			X			
RAISTRICKIA	X			X				
SCHULZOSPORA							X	
TRIQUITRITES				X				

TEXT-FIG. 6—Stratigraphic distribution of spore genera from Carter and Shell wells. C-1, C-2, etc., apply to the Carter well; S-1 to the Shell well. Intervals from which the samples were taken are indicated in feet. The Pennsylvanian section in the Carter well was from 2252 to 6988 feet; the Pennsylvanian section in the Shell well was from 790 to 2895 feet.

pinch out in this area or else the coal was removed or lost in the sampling of the well cuttings. From the limited information available, the Pennsylvanian sequence in this well seems to correspond with the bottom part of the section in the Young-Henderson well. This conclusion is reached because of the presence of *Schulzospora* in level S-1 (the only coal which yielded spores), a genus which first appears in the Young-Henderson well at level Y-10 and lower.

It must be emphasized that with the small amount of coal available for maceration from the well samples and with the identification of spores primarily to the generic level that all conclusions drawn from this information are tentative. More information could no doubt be obtained with larger coal samples and additional identification of spore species.

DISCUSSION

The present study has provided an opportunity to record the presence of spore genera from a portion of the Pennsylvanian section which is poorly known and affords an opportunity to compare the results with data from Europe and Asia as recorded by Potonié & Kremp (1954).

It is now known that *Calamospora*, *Densosporites*, *Endosporites*, *Granulatisporites*, *Laevigatosporites*, *Reticulatisporites*, and *Triquitrites* occur in the lowermost Pennsylvanian coal beds from Mississippi. This information conforms with the data recorded from both Europe and Asia.

Raistrickia, *Punctatisporites*, and *Schulzospora* are present in the lower coal zones from Mississippi and are present in roughly comparable zones in Asia, but, at least in the light of present information, these forms are lacking from European coal beds of this interval.

Florinites, which is present in the lowermost coals of Mississippi, is lacking from apparently comparable coal zones in both Europe and Asia.

The most abundant spore in nearly all the

maceration samples was *Lycospora pseudoannulata*. In Illinois this species ranges from the basal Pennsylvanian to the upper Tradewater (Kosanke, 1950). Such abundance and such a long and continuous range suggests that the parent plants, members of the arborescent lycopods (Felix, 1954), were important members of the early Pennsylvanian vegetation.

As pointed out previously, the major limiting factor in this study was the amount of coal available for maceration from the well samples. This factor could be avoided by following the sampling procedure of Taylor *et al.* (1944) who reported obtaining continuous flow samples of well cuttings from the sample trough with a sieve. The use of a sieve in collecting coal from well cuttings is valuable since the specific gravity of coal is only 1.25 to about 1.5 and consequently frequently floats in the mixture of water and drilling mud and is thus lost as the mixture flows over the tail-gate of the sample box unless adequate measures are taken to insure the collecting of large amounts of coal. If studies similar to this one are to be undertaken in the future, more adequate sampling will allow the collection of more coal from the well cuttings and will thus provide a more representative sample of the coals in the well which can be used for spore studies.

SUMMARY

A study of macerated coals from three wells in Mississippi which penetrated Pennsylvanian rocks indicates that spores which might be of use in correlation from one area to another can be isolated from well cuttings. But it was also obvious that much more coal is necessary than is present in ordinary well cuttings in order to have a better representation of the coal zones.

From the information derived from the maceration of the outcrop samples from Walker County, Alabama, and the coals from the three wells, no definite correlations could be made, but it was shown that the coals from the wells and from Alabama outcrops are all Pottsville in age.

The spores present in the lowermost coals of the Young-Henderson well provided information extending the stratigraphic range of several genera farther into the lower Pennsylvanian in North America. This corresponds in most cases with information published by Potonié & Kremp (1954) from Europe and Asia. *Florinites*, which is found in the lowermost coals in the Young-Henderson well, is an exception. It does not seem to have any comparable zone in the lower Pennsylvanian sections in Europe or Asia as far as is presently known.

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PALEONTOLOGICAL NOTES

LATE CRETACEOUS FOSSIL LOCALITY, EASTERN PARRAS BASIN, COAHUILA, MÉXICO

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HIPOLITO

Recent stratigraphic studies of the Difunta Group (Gulfian-Midwayan) of the eastern part of the the Parras Basin, northeastern Coahuila and western Nuevo León, México, have disclosed exposures (see Text-figure 1) which contain abundant dinosaur and marine molluscan remains in close stratigraphic association in the lower portion of the group (Text-figure 1). The presence of the ceratopsian dinosaur *Monoclonius* extends the geographic range of the genus far beyond its previous most southerly reported occurrence. The close stratigraphic association of dinosaurs and marine mollusks, particularly abundant cephalopods, affords an unusual opportunity to compare age relationships based on continental and marine organisms.

To date, approximately 60,000 feet of strata in various localities have been measured and described in an area of approximately 5000 square miles. Two gross lithic units have been differentiated in the Difunta sequence in this area. They are: (1) a gray to brown fossiliferous sand and shale sequence which divides into four southward thinning tongues separated by (2) red sands, silts, and shales, mostly nonfossiliferous, which thin north and east into the gray-brown sequence. Both facies are calcareous and conglomeratic beds are present from place to place in each. The predominantly arenaceous-argillaceous Difunta Group possesses a maximum thickness of approximately 11,000 feet in this area where it rests with gradational relationships on the dark, argillaceous-calcareous Parras-Méndez strata and appears to grade laterally eastward into the same lithic unit.

Basic field studies in this area were conducted between June 1 and September 15, 1959, by Donald R. Boyd, Robert H. Forde, Robert M. Lawrence, Kenneth G. Martin, William P. Wilbert, and James A. Wolleben, graduate students at Louisiana State University, under the direction and supervision of Clarence O. Durham, Jr. and Grover E. Murray. These studies were conducted under the auspices of National Science Foundation Research Grant (NSF-G5658) at Louisiana State University (Grover E. Murray, Senior Investigator) for basic stratigraphic studies in northeastern Mexico. The locality was first located by Boyd and Lawrence during the course of measurement of the lower portion of the Difunta in the area shown on Text-figure 1. Subsequently, the locality was examined and collections made on different occasions by Boyd, Martin, Wolleben, Murray, and John A. Wilson of the University of Texas.

Particular attention is directed to the fact that geologists wishing to visit this locality should not attempt to do so except with proper advance planning. A large arroyo exists between the locality and the village of Hipolito and it is not, to our knowledge, traversable in standard automotive vehicles. Four-wheel drive vehicles or tandem-trucks with low-range transmissions can make the crossing except in periods of high-water. Horses may be rented in the village of Hipolito. In any event, an adequate water supply and repair tools, if vehicles are used, should be carried.

The fossil locality under consideration (Text-figure 1) is located around and downslope from the highest hill on the westernmost, west-facing Difunta cuesta on a bearing N 85°E from the village of Hipolito. The fossils occur in the upper portion of what appears to be the lowest gray-brown unit of the Difunta (Text-figure 1) but their exact distance above the top of the Parras shale has not been determined. Just southwest of the crest of the cuesta, dinosaur remains are present 980 feet above the base of the cuesta

TEXT-FIG. 1—Maps and cross section showing position of Cretaceous fossil locality.

in a predominantly argillaceous sequence underlain by a resistant sandstone. The mollusks are found 50 feet higher, also in a predominantly argillaceous sequence.

Although the marine mollusks from this locality have not been studied in detail at this time, at least four genera of gastropods, numerous pelecypods including several species of *Ostrea* and *Inoceramus*, and many specimens of the cephalopod *Sphenodiscus lenticularis* have been identified. The latter is quite common in Navarroan beds in Texas and is presumed to indicate an approximately equivalent age for the lower part of the Difunta of this area.

Remains of at least four different dinosaurs have been found in the general area to date. Specimens collected from this locality have been identified by J. A. Wilson, University of Texas, and E. H. Colbert, American Museum of Natural History, as (1) *Monoclonius*, an ornithischian dinosaur of the suborder Ceratopsia (horned dinosaurs) and (2) hadrosaurs (trachodonts) which presently have not been identified generically. The *Monoclonius* suggests approximately a Bellyriveran (Montanan = approximately Tayloran and Navarroan) age for these beds (letter of December 4, 1958 from J. A. Wilson to G. E. Murray).

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NOTE ON LOWER TERTIARY AND UPPER CRETACEOUS OSTRACODA FROM NEW JERSEY

JOHN K. ADAMS
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Ostracoda are present in the sediments of late Cretaceous and early Tertiary age in New Jersey, but they have received only slight attention since 1936, when P. H. Jennings described a microfauna from the Monmouth and basal Rancocas groups. The formations which make up these two groups include: Monmouth group, the Navesink marl, the Red Bank sand, and the Tinton sand; Rancocas group, the Hornerstown marl and the Vincentown sand (Table 1.).

Jennings identified and described 30 species of ostracods in his paper. He stated that 5 species occurred in the Hornerstown marl; 23, in the Navesink marl; and 15, in the Mt. Laurel sand. He showed a clear difference between the Cretaceous and Tertiary ostracod faunas, however, his paper had no discussion of the ostracods from the Red Bank or Vincentown sands.

This writer has recognized a fauna of 26 ostracod species from the Red Bank sand and 25 species from the Vincentown sand. These faunas are listed here for the first time.

TABLE 1—STRATIGRAPHIC SECTION FOR PART OF THE UPPER CRETACEOUS AND LOWER TERTIARY OF NEW JERSEY

Group	Formation	Age
Rancocas	Vincentown sand	Early
	Hornerstown marl	Tertiary
		?
(unconformity)		
Monmouth	Tinton sand	Late
	Red Bank sand	
	Navesink marl	Cretaceous
	Mt. Laurel sand	

OSTRACODA FROM THE RED BANK SAND OF NEW JERSEY

Cythereis pulchra (Jennings)
C. communis (Israelsky)
C. curta (Jennings)
C. aff. *C. huntensis* (Jennings)
C. aff. *C. pidgeoni* (Berry)
Brachycythere arachoides (Berry)
B. ledaforma (Israelsky)
B. jerseyensis (Jennings)
B. sp.
Bairdoppilata viticula (Jennings)
B. sp.
Haplocytheridea fabaformis (Berry)
H. macropora (Alexander)
H. cf. *H. punctura* (Schmidt)
H. sp. *1*
H. sp. *2*
H. sp. *3*
Cytheridea cf. *C. punctilifera* (Jennings)
Antibythocypris? gooberi (Jennings)
Bythocypris aff. *B. parilis* (Ulrich)
Orthonotacythere sp.
Loxoconcha sp.
Cytherella sp. *1*
C. sp. *2*
C. sp. *3*
C. sp. *4*

OSTRACODA FROM THE VINCENTOWN SAND OF NEW JERSEY

Eucythere triordinis (Schmidt)
Paracytheridea sp.
Cythereis plusculmenis (Schmidt)
C. pauca (Schmidt)
C. bassleri (Ulrich)
C. aff. *spiniferma* (Jones & Sherborn)
C. sp.
Brachycythere harlani (Jennings)
B. betzi (Jennings)
B. sp. *1*
B. sp. *2*
B. sp. *3*
Alatacythere sp.
Loxoconcha sp. *1*
L. sp. *2*
Xestoleberis cf. *X. longissima* (Schmidt)
Bairdoppilata pondera (Jennings)
B. delicatula (Jennings)
B. viticula (Jennings)
Bythocypris parilis (Ulrich)
Cytherelloidea cf. *C. howei* (Swain)
Paracypris strecca var.
Haplocytheridea sp.
Cytherella sp. *1*
C. sp. *2*

The writer has also found ostracods in the upper 5 feet of the Hornerstown marl. All the Hornerstown species are also present in the Vincentown sand.

An examination of the lists of ostracods from the Red Bank and Vincentown sands and a comparison between the Cretaceous and Tertiary forms, described by Jennings, reveal that there is a great difference between the Upper Cretaceous faunas and

those from the Lower Tertiary. Ostracods are not abundant enough to be used in precisely locating the Cretaceous-Tertiary boundary in New Jersey, but where ostracods are present there should be no difficulty in recognizing them as either Cretaceous or Tertiary.

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STRUCTURE AND COMPOSITION OF ASSOCIATED NEURODONTIFORMES AND *ASTRASPIS* SCALES FROM THE HARDING FORMATION OF COLORADO

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The chemical composition of the Neurodontiformes has recently been discussed by Rhodes & Wingard (1957), who concluded that the approximate composition was that of calcium metaphosphate $Ca_3(PO_3)_2$. Ellison (1944) concluded that some Pennsylvanian conodonts which he x-rayed had an apatite $Ca_5(PO_4)_3$ (F, Cl, OH) structure and composition. Inasmuch as the Rhodes & Wingard data were rather inconclusive, and Ellison dealt with lamellar forms in his study, a more detailed examination of the chemical and structural composition of the Neurodontiformes seemed appropriate for better understanding of their zoological affinities.

The specimens studied were extracted from the Harding Formation of Colorado. Both the Neurodontiformes and the *Astraspis* scales studied were from the same hand specimen. The material was hand picked, and only clean, whole individuals were used. It was found that approximately fifty individual neurodonts would supply enough powder for a standard x-ray diffraction examination. Less than one whole *Astraspis* scale supplied a sufficient volume of material for x-ray examination. Several runs were made on each sample to insure accuracy. The samples were studied using nickel-filtered copper radiation in a 114 mm. camera.

Silverman, Fuyat, & Weiser (1952) demonstrated that the various types of apatite can be distinguished by variations in the spacings between the (231) and (004) lines in x-ray powder films. This technique has been applied to many specimens of vertebrate material representing many different species and ages in a study being conducted at The Rice Institute under the direction of H. J. Sawin and J. K. Osmond. It has been found that almost all vertebrate materials studied can be placed in the hydroxylapatite or fluorapatite categories. The Neurodontiformes and the *Astraspis* scales from the Harding Formation fall somewhat outside the normal range of the other vertebrate material examined.

	Plane indices	2θ	Δ^1 mm.
Hydroxylapatite	231	50.6	2.7
	004	53.3	
Fluorapatite	231	50.8	2.5
	004	53.3	
Carbonate-fluorapatite	231	50.9	2.3
	005	53.2	
Neurodontiformes	231	50.95	2.40
	004	53.35	
Astraspis scales	231	50.95	2.35
	004	53.30	

[1] Δ = difference between 2θ values (in mm.) for lines (231) and (004).

Taken in part from Silverman, Fuyat, & Weiser (1952).

TABLE 1—D/N VALUES

Astraspis	*Neurodonts*	*Apatite (file)*
8.11		
5.24		
4.69		
4.04	4.00	
3.85	3.82	3.80
3.40	3.40	3.45
3.16	3.13	3.11
3.05	3.05	
2.79	2.78	2.82
2.69	2.68	2.73
2.60	2.60	2.56
2.50	2.51	2.54
	2.44	
	2.32	
	2.27	2.27
2.24	2.24	
2.13	2.12	2.13
2.05	2.06	2.04
1.99		
1.97		
	1.93	1.94
1.88	1.87	1.89
1.83	1.83	1.83
1.79	1.79	1.81
1.77	1.77	1.77
1.74	1.74	1.75
1.72	1.72	1.72
1.63	1.63	1.65
1.60	1.61	1.62
1.57	1.58	1.59
1.53	1.53	1.53
1.50	1.50	1.50
1.47	1.47	1.47
1.45	1.45	1.45
1.42	1.42	1.43
1.40	1.40	1.40
	1.37	
1.34	1.33	
1.31	1.31	1.31
	1.30	
1.27	1.27	1.28
1.26	1.25	1.25
1.23	1.23	1.24
1.21	1.22	1.22
		1.19
		1.18
		1.16
		1.15
		1.12
		1.10

The Δ values of the Neurodontiformes and the *Astraspis* scale are both somewhat smaller than that of pure fluorapatite, and tend toward the accepted value for carbonate-fluorapatite. In this respect they are distinct from all other vertebrate bone material studied. The fact that the Neurodontiformes and the *Astraspis* scales from the Harding fall into a discrete chemical group might well indicate a genetic relationship between these two forms. Inasmuch as *Astraspis* is of undoubted vertebrate affinities, it seems only reasonable to suggest that this evidence further reinforces the proposed vertebrate affinities of the Neurodontiformes.

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JOURNAL OF PALEONTOLOGY, V. 34, NO. 2, P. 374–375, MARCH, 1960

REVIEW

LEHRBUCH DER PALÄOZOOLOGIE, by A. H. Müller. Band I: ALLGEMEINE GRUNDLAGEN. 322 p., 177 text-figs., 1957. Band II. INVERTEBRATA, Teil 1: PROTOZOA—MOLLUSCA 1. 566 p., 652 text-figs., 1958. G. Fischer, Jena. (Prices: Bd. I DM 32.50; Bd. II, T. 1 DM 74.00)

These are the first two installments of a textbook of paleontology which, when complete, will consist of three volumes, printed in four parts. It promises to be the most comprehensive paleontological treatise in the German language since Zittel's "Grundzüge," the last edition of which appeared in 1924. Lest the prospective reader should be apprehensive of the language barrier, let it be stated at once that the present volumes are written in a clear and comprehensible style; that the average length of sentence is of the order of two to three lines; and that, while many sentences are shorter, the reviewer has found few as long as four lines or more.

The first volume should be particularly welcome to non-German readers, because it has no exact counterpart in English. It deals at some length with matters which in most paleontology books are crowded into a brief introductory chapter: processes of fossilization, principles of taxonomy, evolution, and paleoecology.

Over the last few decades, at least since Johannes Walther around 1890, there has been a great volume of research in Germany on all aspects of fossilization, but the accumulated results have received less recognition abroad than they deserve. Generally, in paleontology texts, fossils appear as a kind of *deus ex machina*—they are there, but we learn little about how and why they got to where we find them. Now, Dr. Müller's 100-page chapter on "Fossilisationslehre" presents an able summary of German research in the field of fossilization and a welcome listing of more than 100 of the most important publications.

Logically, the inquiry starts at the moment an organism dies, because it is at this point that it begins—at least potentially—to turn into a fossil. "Fossilisationslehre" studies the vagaries of organic remains from this moment and until they become ingredients of sedimentary rocks, as we find them today. In other words, it is concerned with all processes which are responsible for and accompany the passage of an organism from the biosphere into the lithosphere. Following usual German practice, Dr. Müller divides the field into "Biostratinomie" and "Fossildiagenese." The former deals with the fate of the organism from the moment of its death until its remains (if any) become firmly and finally lodged in a sediment. At this stage diagenesis begins which, as is customary in German literature, is defined as the sequence of all alterations which affect sediments and fossils and which are not attributable to metamorphism or weathering.

The term "Biostratinomie" (originally spelled "Biostratonomie") was coined by J. Weigelt about 40 years ago, but has been little used in English literature. Dr. Müller's treatment of the subject proceeds from discussion of the fate of the organic substance and the influence its decay may exert on sedimentation and the embedding of fossils to the formation of "allochthonous thanatocoenoses" to which most fossiliferous deposits belong. It is here that difficulties of comprehension may become most irksome to the reader (and not necessarily only to the non-German one), because a rich German vocabulary, bolstered by large numbers of new compound words (not to be discovered in dictionaries), has been built up over the years to record and describe phenomena and processes in this fascinating borderland between biology, biochemistry, sedimentation, oceanography, limnology, physiography, and other sciences. The subtle difference between *Einregulung* and *Einsteuerung* will not be immediately apparent to everyone and the reviewer himself has been groping unsuccessfully for adequate English equivalents of such words as *Schillhorizont*, *Frachtsonderung*, *Spülsaum*, *Lesedecke*, and *Prägekern*. These and other terms can be rendered in English only as strings of genitives or as relative sentences. Fortunately, the concepts behind most such words are conveyed by good illus-

trations which will enable the reader to concoct his own translations.

The chapter on evolution (Ger.: Phylogenetik) lacks consideration of much of modern English and American literature in this field. For many phyla and lower categories the author presents diagrams, first published in his "Grossablauf der stammesgeschichtlichen Entwicklung" in 1955, attempting to show the numerical and temporal distribution of genera or families in the geologic record. At least some of these are based on incomplete data and may eventually have to be greatly modified. Thus, only about one-half of the recognized number of ammonoid genera and about one-fourth of the known genera of nautiloids have been used in the construction of diagrams for these two groups.

The chapter on paleoecology and paleophysiology is of considerably greater interest, because here again the author leans heavily on German literature which is far from well known abroad. Unfortunately, however, there is virtually no reference to the large volume of paleoecological research carried on outside Germany. The treatment follows the more comprehensive works of Abel, Rudolf Richter and Dacqué (whose "Biologische Formenkunde" is inexcusably omitted from the bibliography).

The first volume concludes with a chapter on techniques of paleontological preparation (or "development" in British usage). This is useful as far as it goes, though we miss discussion of many modern techniques such as ultrasonic separation, fluorization, acetate peels, latex impressions and replicas, staining, to mention only some that might have been included.

The systematic part of the work has so far been completed up to and including the Pelecypoda. The treatment is conventional, illustrations adequate in most cases. The taxonomy is modern. Descriptions of systematic categories down to the family level are reasonably complete, while the problem of selection of genera in a book of this size will always be dictated in part by personal preference and experience. Morphological descriptions on the generic level would have gained much in clarity had they been stated in terms of simple differential diagnoses. For example, if the description of the Myalinidae includes references to the obliquely oval shell form and the straight and edentulous hinge, it is redundant to repeat this information in the diagnosis of Myalina. By weeding out such dead wood both size and price of the second volume could have been reduced.

As is almost unavoidable, there are minor inaccuracies in stated ranges and distribution of genera. Contrary to explicit or implied statements *Sphaerospongia*, *Productella*, *Trigonosemus*, *Punctospirifer*, and *Syringothyris* do occur in Australia. *Conchidium* is found in the Middle Silurian only. *Spirifer s. str.* is restricted to the Carboniferous. "*Aucella*" is now more commonly known as *Buchia* and "*Panopaea*" as *Panope*. There are also inconsistencies in that distribution data are given for many genera, but not for all.

The entire work will make a valuable addition to any paleontological library.

CURT TEICHERT
U. S. Geological Survey
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SOCIETY RECORDS AND ACTIVITIES

SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

Program for S.E.P.M. Atlantic City Meeting

W. J. Plumley, Technical Program Chairman

RESEARCH COMMITTEE SYMPOSIUM: PALEONTOLOGICAL AND MINERALOGICAL ASPECTS OF POLAR WANDERING AND CONTINENTAL DRIFT

1. CLIMATIC ZONING DURING THE GEOLOGIC PAST, G. W. Bain, Amherst College, Amherst, Massachusetts
2. THE TECTONIC APPROACH TO THE PROBLEM OF THE DISPERSION OF THE CONTINENTS, S. W. Carey, University of Tasmania, Hobart, Tasmania
3. PALEONTOLOGICAL EVIDENCE FOR CONTINENTAL DRIFT IN THE SOUTHERN HEMISPHERE, Kenneth Caster, University of Cincinnati, Cincinnati, Ohio
4. SOME RECENT EVIDENCE ON CONTINENTAL DRIFT AND APPARENT POLAR WANDERING, E. R. Deutsch, Imperial Oil Ltd., Calgary, Alberta, Canada
5. THEORIES OF GLACIATION AND ICE-AGE FORMATION, Maurice Ewing, Lamont Geological Observatory, Palisades, New York
6. CORAL GROWTH PATTERNS AS PALEOGEOGRAPHIC TOOLS, A. G. Fischer, Princeton University, Princeton, New Jersey
7. PRECAMBRIAN EVIDENCE FOR POLAR WANDERING, W. C. Gussow, Union Oil Company of California, Calgary, Alberta, Canada
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9. DEEP-FOCUS EARTHQUAKES IN SOUTH AMERICA AND THEIR POSSIBLE RELATION TO CONTINENTAL DRIFT, H. J. Harrington, Tennessee Gas Transmission Company, Houston, Texas
10. DEEP SEA TOPOGRAPHY, B. C. Heezen, Lamont Geological Observatory, Palisades, New York
11. IDEAS ON CRUSTAL SHIFT, Ting Ying H. Ma, National Taiwan University, Taipei, Taiwan
12. LOWER HURONIAN ALGAL COLONIES AND THEIR RELATIONSHIP TO POLAR POSITION, S. C. Nordeng, Michigan College of Mining and Technology, Houghton, Michigan
13. MEASUREMENTS OF PALEOMAGNETISM, S. K. Runcorn, King's College, Newcastle Upon Tyne, England
14. BIOGEOGRAPHY AND CONTINENTAL DRIFT, Albert Wolfson, Northwestern University, Evanston, Illinois

PALEONTOLOGY AND STRATIGRAPHY

1. INTERPRETATION OF GROWTH STAGES AND SPECIFIC VARIATION IN PALEOZOIC CONODONTS, Alan Scott, University of Texas, Austin, Texas, and Charles Collinson, Illinois State Geological Survey, Urbana, Illinois
2. RECLASSIFICATION, LIVING HABITS, AND SHELL MINERALOGY OF CERTAIN LATE PALEOZOIC SEDENTARY FORAMINIFERA, Lloyd G. Henbest, U. S. Geological Survey, Washington, D. C.
3. MICROSTRATIGRAPHY AND THE SEARCH FOR PERMIAN FRESHWATER BIOFACIES, Paul Tasch, University of Wichita, Wichita, Kansas
4. THE USE OF FRESH WATER PLANTS AND ANIMAL FOSSILS IN INTERPRETING THE PALEOECOLOGY OF LAKES, D. G. Frey, Indiana University, Bloomington, Indiana
5. STRATIGRAPHIC CORRELATIONS BY DIATOMS, K. E. Lohman, U. S. Geological Survey, Washington, D. C.
6. CULTIVATION OF OSTRACODES AS A MEANS OF UNDERSTANDING ENVIRONMENTAL INFLUENCES ON POPULATIONS, C. D. Wise and L. S. Korniker, University of Texas, Institute of Marine Science, Port Aransas, Texas
7. A FLEXIBLE APPROACH TO THE INTERPRETATION OF FOSSILIFEROUS SAMPLES, R. M. Jeffords, Humble Oil & Refining Company, Houston, Texas
8. MULTIFACTOR FACIES ANALYSIS, John Imbrie, Columbia University, New York, New York
9. SUBSURFACE STRATIGRAPHIC POTENTIAL OF SOME CAMBRIAN FOSSILS, A. R. Palmer, U. S. Geological Survey, Washington, D. C.
10. CONOSTICHUS AS AN ECOLOGICAL INDICATOR, C. C. Branson, University of Oklahoma, Norman, Oklahoma
11. FACIES OF THE COTTONWOOD LIMESTONE, L. F. Laporte, Brown University, Providence, Rhode Island

12. BIOFACIES AND LITHOFACIES STUDY OF EIGHT TIME-ROCK UNITS FROM THE SOUTH TEXAS TERTIARY, A. R. Campbell, Shell Development Company, Houston, Texas
13. SOME STRATIGRAPHIC INTERPRETATIONS FROM THE COCCOLITHOPHORIDS AND RELATED MICROFOSSILS (TO BE READ BY TITLE), M. N. Bramlette, Scripps Institution of Oceanography, La Jolla, California

SEDIMENTARY PETROLOGY AND MINERALOGY

1. GEOCHEMISTRY OF SURFICIAL SEDIMENTS IN THE GULF OF MEXICO, A.P. Pinsak, Indiana Geological Survey, Bloomington, Indiana, and H. H. Murray, Georgia Kaolin Company, Elizabeth, New Jersey
2. MINERALOGICAL FEATURES OF DEEP CLAYS, CAILLOU ISLAND, LOUISIANA, P. F. Kerr and Jonathan Barrington, Columbia University, New York, New York
3. CLAY MINERALOGY OF VARIOUS FACIES OF SOME CHESTER FORMATIONS, T. W. Smoot, Illinois State Geological Survey, Urbana, Illinois
4. CARBONATES FROM OIL, S. R. Silverman, D. W. Levandowski, and L. C. Bonham, California Research Corporation, La Habra, California
5. GENESIS OF PRIMARY STRUCTURES IN ANHYDRITE, C. M. Riley and J. V. Byrne, Humble Oil & Refining Company, Houston, Texas
6. PETROLOGY AND PETROGRAPHY OF CORDILLERAN UPPER PALEOZOIC CARBONATE ROCKS, H. J. Bissell, Brigham Young University, Provo, Utah
7. THE REVERSIBILITY OF CHERT-CARBONATE REPLACEMENT, T. R. Walker, University of Colorado, Boulder, Colorado
8. MARTINSBURG-REEDSVILLE PALEOCURRENTS, E. F. McBridde, University of Texas, Austin, Texas
9. DEPTH SEQUENCE OF DIAGENETIC MINERALS IN DEVONIAN AND CARBONIFEROUS SEDIMENTS, TAMWORTH TROUGH, NEW SOUTH WALES, Keith A. W. Crook, University of Alberta, Edmonton, Alberta, Canada
10. DISTINCTION OF SHORELINE ENVIRONMENTS IN NEW JERSEY, W. E. Biederman, Jr., Cities Service Research and Development Company, Tulsa, Oklahoma

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PERMIAN BASIN SECTION ANNUAL MEETING AND FIELD TRIP

The annual technical and business meetings of the Permian Basin Section, Society of Economic Paleontologists and Mineralogists, will be held Thursday, April 14, 1960, in Abilene, Texas. General Chairman is Dr. John P. Brand, Texas Technological College, Lubbock, Texas.

A field conference to study the Pennsylvanian and lower Permian is planned for Friday and Saturday, April 15 and 16, 1960. General Chairman is Mr. Thomas Hambleton, Texaco, Box 1270, Midland, Texas.

Details of both the technical program and field conference will be announced at a future date.

CARL ULVOG, President

PACIFIC COAST SECTION ANNUAL MEETING AND FIELD TRIP

The Pacific Coast Section, S.E.P.M., will sponsor their annual dinner meeting and field trip on April 15 and 16, 1960. The Friday evening dinner meeting will be held at The Hacienda, Fresno, California. Mr. Max Payne will present a paper on the stratigraphy of the Panoche Hills. He will also lead the field trip on Saturday morning. The geology and paleontology of rocks of Cretaceous age will be studied in the vicinity of the Panoche Hills, west side of San Joaquin Valley, Fresno and Merced Counties, California. Dr. Alfred Loeblich is the Field Trip Chairman.

R. L. BROOKS, Secretary-Treasurer

SOUTHEASTERN GEOLOGICAL SOCIETY 9TH FIELD TRIP

The Southeastern Geological Society will hold its 9th Field Trip in central Florida on May 6 and 7, 1960. The field trip will be conducted to some classic outcrops of Crystal River formation, Hawthorn formation, Alachua formation, Bone Valley formation, unnamed coarse clastics, and Pleistocene. It will start from Gainesville, Florida, at 8:00 A.M., May 6, and will disperse in the vicinity of Bartow on the afternoon of May 7. Transportation will be by private car, and the Society will furnish transportation to persons who so desire. The field trip will be led by E. W. Bishop and E. C. Pirkle; H. K. Brooks will act as commentator.

This field trip will be by *preregistration only*, and persons interested in attending should write to the Southeastern Geological Society, P. O. Box 841, Tallahassee, Florida, not later than April 29.

S.E.P.M. OPINION REFERENDUM

At the Business Meeting of the S.E.P.M. last year in Dallas, Texas (March, 1959), your Council was requested to poll the entire voting membership of the Society, requesting that they indicate whether they preferred a single or double slate of candidates for S.E.P.M. offices. This Opinion Referendum was mailed to all active members on August 31, 1959. The results, as of March 1, 1960, are as follows:

167—favored a single slate of candidates
293—favored two candidates

The Council is, therefore, bound by the majority vote, to instruct the nominating committee to submit a ballot of two nominees for each of the offices of President, Vice-President, and Secretary-Treasurer.

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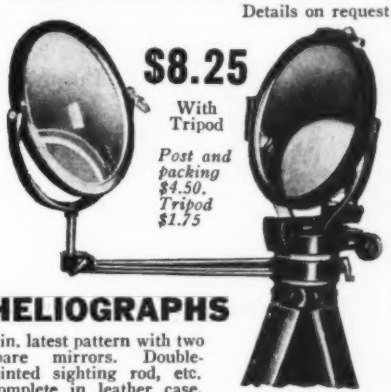

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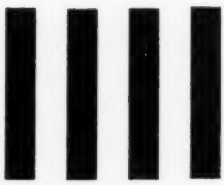

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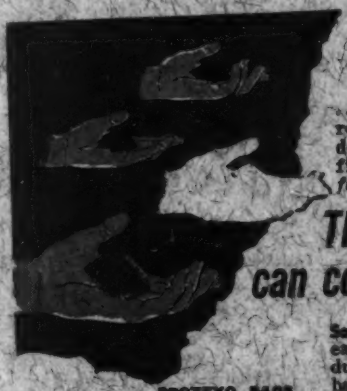

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